MODERN SCIENCE PROBLEMS

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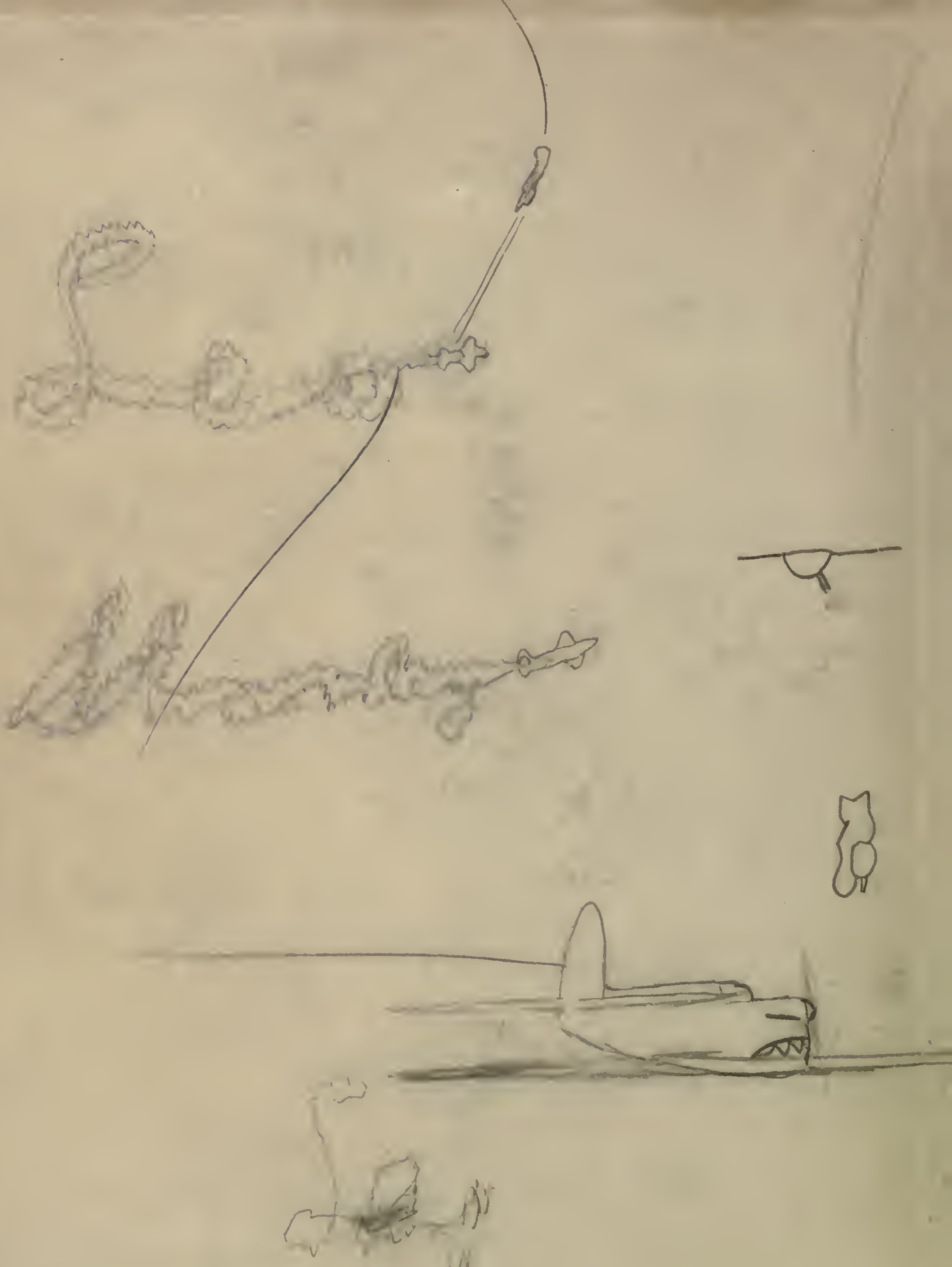

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MODERN SCIENCE PROBLEMS

A TEXTBOOK IN GENERAL SCIENCE

BY

ELLSWORTH S. OBOURN, B.S.

HEAD OF THE SCIENCE DEPARTMENT
JOHN BURROUGHS SCHOOL
CLAYTON, MISSOURI

AND

ELWOOD D. HEISS, Ph.D.

HEAD OF THE SCIENCE DEPARTMENT
STATE TEACHERS COLLEGE
EAST STROUDSBURG, PA.

WEBSTER PUBLISHING COMPANY

1808 WASHINGTON AVENUE ST. LOUIS, MISSOURI

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FOREWORD TO TEACHERS

General science has attained a place in the curriculum of the modern secondary school because it has seemed to provide for certain needs in the growth of the student through its contributions to the aims of a liberal education.

Science is continuously growing in importance in everyday life. Varied responses and frequent adjustments are required by a complex environment. Such responses and adjustments demand (1) an understanding of those concepts of science which have influenced man's thinking; (2) the ability to apply certain fundamental principles effectively in the control and interpretation of environmental forces; (3) the formation of habits of work, and attitudes toward scientific phenomena which will enable an individual to cope with the situations of a changing world.

This book has grown out of long experience in attempting to solve some of the problems of classroom instruction in general science, such as securing and holding the interest of pupils; the provision for individual differences in students; the closer coördination of laboratory and textbook work; provision for effective mastery of laws, principles, and facts; fostering a problem-solving attitude in the mind of the pupil; and the guidance of his study.

Based upon a detailed analysis of the most commonly used textbooks, syllabi, and representative courses of study, the book is thoroughly sound in its construction. It has had experimental tryouts and has been revised in the light of these findings. It has also had the criticism of teachers and pupils who have used it.

The organization and the plan of the book are distinctive from the following points of view:

1. The book provides the necessary tool materials for a complete course in general science, workbook exercises, laboratory manual, and textbook. These parts do not appear as separate sections of the book, but are carefully integrated in the development of the course. There is also a separate workbook to accompany the text.

2. The book is based on the unit-topic-problem plan of organization.

3. The interest of the pupil is secured through introductions which serve to give an overview of each unit and at the same time focus the attention on its major points. The development from topic to topic is natural, and the student is challenged to work by the appeal of achievement as he progresses through a unit. Challenging exercises have been set into the books which serve to help the pupil make application of the materials learned while at the same time giving training in the elements of scientific thinking.

4. Provision for the development of scientific habits of mind is made by fostering a problem-solving method throughout. In the development of each topic the student is called upon to solve carefully selected problems.

5. Individual differences of rate and capacity in learning are provided for by the book. A student works at his own rate through a unit. A list of supplementary activities accompanies each unit of instruction and provides several types of activity suited to a variety of interests.

6. The study of the pupil is carefully guided. In the development of each topic of a unit the attention of the student is directed by study suggestions to important and difficult principles. New words and phrases likely to be encountered are defined.

7. The book closely coördinates the laboratory or demonstration work with the text. Experiments which may be done by either pupil or teacher are included at the time in the solution of a problem when first-hand knowledge is most helpful. The text material which follows the experiments provides the pupil with a well-rounded knowledge of a topic. Simple equipment, available in any community, is used in the majority of the experiments. Where more expensive pieces are used, simple inexpensive substitutes are usually described.

8. Provision is made for wide reading on the part of the pupil. To enable him to secure a broad view of each topic and learn not to depend for information upon a single source, page reference to most of the commonly used general science textbooks is made in each topic of every unit. A list of general supplementary references on each topic is also included.

9. A high degree of mastery of the laws, principles, and facts is assured. In the development of each topic there is included a statement of aims against which a pupil may check his knowledge. A short mastery test which enables the instructor quickly to catch unmastered items and provide remedial work at once is also included with each topic.

10. The book may be used with any teaching method. Flexible in organization and plan, it is readily adaptable to the individual, group, or any other scheme of class organization.

11. The responsibility for learning is largely assumed by the pupil, thereby freeing the teacher for the more important duties of stimulator, guide, and helper. The grade placement of the book will be largely determined by the organization of the system in which it is used. It may be used in either the eighth or the ninth year.

FOREWORD TO STUDENTS

This book will be your guide in the study of general science. If you are to get full benefit from it, you should first become familiar with its parts. The questions below will help to acquaint you with the book.[1]

1. With what part of general science does this book deal? (Study the table of contents before answering.)

2. What are the large divisions of the book called?

3. How many of these large divisions are there?

4. Into what are these large divisions divided? (See pp. 21, 76, 86.)

5. What is a problem?

6. How are "problems" in the book related to "topics"? (See pp. 1, 7, 103.)

7. The book gives you aids of several kinds in solving problems.

a. What do you observe about suggestions for study on pp. 1, 12, 21, 119.

b. What is an experiment and how can it help in solving problems? (See pp. 2, 8, 21, 111.)

c. Of what value are the "readings" in solving problems? (See pp. 13, 34, 39, 93.)

d. How should you use illustrations in solving problems? (See pp. 161, 172, 190, 203.)

e. What additional helps do you find on pp. 6, 20, 49?

8. What is the purpose of such tests as those on pp. 7, 11, 15, 140.

9. What kinds of additional material are provided for pupils who work more rapidly than others? (See pp. 26, 55, 145, 214.)

From your investigation you will have discovered that each topic develops the problems in bold type at the beginning of the topic. Be careful to make use of the suggestions for study. When you perform an experiment, have the results checked by your teacher before you go to the next experiment. With the knowledge that you gain from the experiments you are ready to secure additional information by reading the textual matter. Try to think of what you read in its connection with your experiments.

Check the success of your study by the list of aims at the end of each topic. Then perform the mastery exercises to find out whether there are any parts of the topic that you should study further. These mastery exercises should be done without the aid of notes or books.

[1] See workbook to accompany this text, p. 1.

CONTENTS

UNIT I. THE OCEAN OF AIR IN WHICH WE LIVE

Did it ever occur to you that you are living at the bottom of a great ocean of air which is far deeper than the deepest ocean of water on earth? In many ways this is similar to an ocean of water: it has great currents like the ocean currents caused by the unequal heating of its parts; in it, as in the ocean, there are many varieties of living things; it has tremendous force when moving, as has water; and it, like water, makes possible one means of transportation and travel.

For many hundreds of years man has been trying to solve the mysteries about air, and the study is still carried on; for even after long years of search much remains to be learned about this great blanket which surrounds our earth. Calculations based upon observations indicate that it is between fifty and two hundred miles in depth. Small balloons carrying recording instruments have reached a height of eighteen miles, while man has gone more than eight miles above the earth's surface in airplanes. In 1932 Professor Piccard of Belgium reached a height of more than ten miles; in 1933 Settle and Fordney reached an altitude of more than eleven and a half miles. The record is now held by Stevens and Anderson, who ascended 72,395 feet or more than thirteen and a half miles on November 11, 1935.

Galileo and Torricelli first measured the pressure of the air; Priestley and Lavoisier studied its composition; Dumont, Langley, and the Wright brothers learned to travel through it.

Life is impossible without air because air contains substances which all life must have. Oxygen, which forms a part of the air, is used by all living things, and carbon dioxide is used by plants in food making. We use air in many ways as we go about our daily lives: in automobiles tires for ease of riding; to stop railroad trains, street cars, and buses by air brakes; in building great buildings, bridges, and tunnels with compressed air hammers and drills; to carry mail, express, and passengers in the airplane and dirigible. In fact, air is so much a part of our existence that every one should learn of its secrets and mysteries. The exercises of this unit will guide you in learning these.

How many of these things about air do you know?

The purpose of this exercise is to assemble the things you already know about air. It will help you in your study of the things which are to come. Write the answers in your notebook.

1. Does air have any weight?
2. How thick is the envelope of air which surrounds the earth?
3. What is a vacuum?
4. What are some devices which make use of a vacuum?
5. What are some machines which make use of compressed air?
6. How should a room be ventilated to secure best results?
7. In what ways is air used for the purpose of transportation?
8. In what ways is air of importance to automobiles?
9. How does air pressure on top of mountains compare with air pressure at the level of the sea?
10. What is the greatest height to which man has gone by means of airplane or balloon?
11. Of what importance is air to sound?
12. How is air used in the construction of bridges and dams?
13. How is air used in the construction of large buildings?
14. How is air used on trains, street cars, and buses?
15. How does a vacuum cleaner work?

TOPIC 1. WHAT WE KNOW ABOUT AIR

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is known about the nature of air and the atmosphere?**
2. **How can the pressure of air be proved and measured?**
3. **What are some of the uses of barometers?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems in the first column. Are they questions which you have wondered about or in which you are interested?

2. Perform the experiments. In doing so, be sure to follow directions, observe what happens, and make notes in your notebook. Your instructor will check results after each experiment.

3. Read carefully the material under this topic. Try to see how the parts fit together to explain the topic. As you read, study the diagrams and pictures.

4. Read something from the books listed as "References for Further Study" (p. 6).

5. Close your book and think over the things you have observed and read in such a way as to organize the topic in your mind.

6. Check your knowledge by means of the section, "What You Should Aim to Acquire from This Study" (p. 7). You will then be ready for the mastery test.

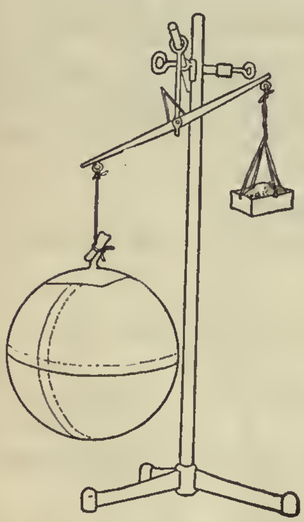


FIG. 1

7. In the study of this topic you may meet some words for the first time. Study them carefully until they become a part of your vocabulary.

altitude—height above a given level.

aneroid—without liquid.

barometer—a device for measuring air pressure.

diaphragm—a thin disk or membrane.

pressure—a push or pull on a unit area such as one square inch or one square centimeter.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 1. Does air have weight?

Secure a simple balance as shown in Figure 1 and counterbalance an empty football or basketball bladder with weights or sand. Pump air into the bladder and close the neck with a rubber band or piece of string and observe what happens. In your notebook[1] enter notes on the experiment and complete the following statements. When air was pumped into the bladder and it was closed, the bladder side of the balance weighed (more, less, the same) ____. This would indicate that air ____.

Experiment 2. Does air exert pressure?

Secure a can like the one shown in Figure 2 or one similar to it, which can be tightly closed. Put about an inch of water into the can and heat it until steam comes from the opening. Close the opening quickly and tightly and cease to apply heat. Let the can cool for a few moments and see what happens. Try to crumple a similar can in your hands. In your notebook[2] write a clear statement of what was done. Complete the following statements. (Air, Steam) ____ filled the can when it was stoppered. When the flame was removed, the ____ began to ____, causing less pressure ____ of the can. The greater ____ of the air on the ____ of the can then caused it to ____.

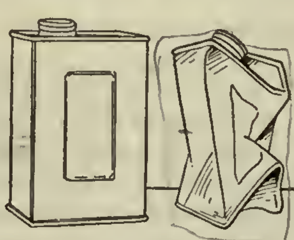


FIG. 2

Under the heading, "Inferences and Conclusions," complete the following statement. The evidence above would seem to indicate that air ____.

Have your notes checked.

If possible, try other experiments to test your conclusion.

Suggestion: Fill a glass very full of water and press a piece of cardboard over the open end. Invert the glass and remove your hand from the cardboard. Record the results in your notebook. Did the experiment support or disprove your conclusion?

Experiment 3. How can air pressure be measured?

Close one end of a piece of glass tube about thirty-two inches in length by rotating it in a gas or alcohol flame. Attach a funnel to the open end of this tube by a short length of tight-fitting rubber tubing. Carefully pour mercury into the funnel until the tube is full. Partly fill a shallow dish with mercury. Placing your finger over the open end of the tube, turn the closed end up. Be careful not to remove your finger from the tube until the open end is under the surface of the mercury in the dish. Support the barometer tube by means of a ring stand as shown in the diagram. Measure the height of the mercury column above the level of the mercury in the dish. Take readings for several days. In your notebook[3] record what was done. Make a table of the measurements of the mercury column for several successive days.

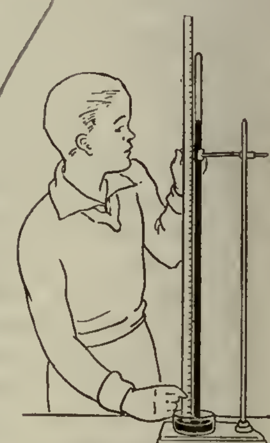


FIG. 3. MEASURING THE HEIGHT OF A BAROMETRIC COLUMN

Under the heading, "Observations and Inferences," complete the following statements. ____ holds the mercury up the tube. The mercury column fell when the tube was inverted because ____ The mercury did not fall all the way down the tube because ____. The space above the mercury column is probably a ____. The height of the mercury column might be measured in what units? The height of the mercury column is an indication of the ____ of the atmosphere. The mercury column balances a column of air as deep as the ____. The mercury column is shorter than the air column because it ____ more, volume for volume. The data from the table seem to indicate that air pressure ____ from day to day. When the pressure increases, the mercury column ____. When the mercury column falls, the pressure ____.

Experiment 4. How does the aneroid barometer measure pressure?

Secure an aneroid barometer similar to the one in Figure 4. Study the working parts carefully, noting particular the round shiny box in the center. Observe the way in which the dial is marked and any words or letters which appear. Compare the reading of the aneroid with the height of your mercury barometer.

[1] See p. 2 of workbook to accompany this text.

[2] See p. 2 of workbook to accompany this text.

[3] See accompanying workbook, p. 3.

Courtesy Taylor Instrument Company

FIG. 4. ANEROID BAROMETER

In your notebook[1] write a clear statement of what was done. Under the heading, "Observations and Inferences," complete the following statements. The dial of the aneroid was marked off in ____ and ____. The air gets to the working parts of the aneroid through ____. The little box in the center has a ____ surface. The words ____, ____, and ____ are printed on the dial of the barometer. The word ____ seems to be associated with a low barometer reading. The word ____ seems to be associated with a high barometer reading. The aneroid barometer read ____ when I made this

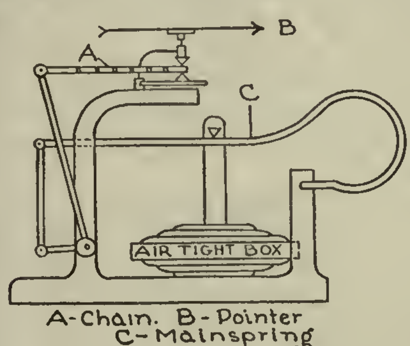


FIG. 5. WORKING PARTS OF THE ANEROID BAROMETER

observation. The barometer may be set for future readings by ____. From my observations I would conclude that the uses of the aneroid barometer are ____.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

Carry an aneroid barometer from the bottom of a hill to the top and note any change in the reading. Infer a cause for this.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is known about the nature of air and the atmosphere? Air is a colorless and odorless mixture principally made up of the two gases, oxygen and nitrogen. Because it is ever present and because we walk through it with ease, we are usually reminded of its presence only as we walk against a strong wind or see the destruction which moving air has caused in a tornado or other wind storm. We ride on cushions of air in our automobiles and bicycles and through the air in airplanes and dirigibles. Air-driven machines aid in quarrying rock, mining coal, erecting great buildings, and tunneling under the earth's surface for subways and railroads. Most important of all, animals need oxygen from the air to keep them alive.

It is a familiar experience that water, oil, or other liquids will not run out of bottles or other containers unless air bubbles in to take the place of the liquid. If you have ever drawn a cup of water from the large inverted water bottles commonly found in office buildings or if you have attempted to drink water from a bottle, you know that as the water comes out air bubbles may be seen going up through the water in the bottle.

The earth is surrounded by a blanket of air which is known to be more than twenty miles in depth. This

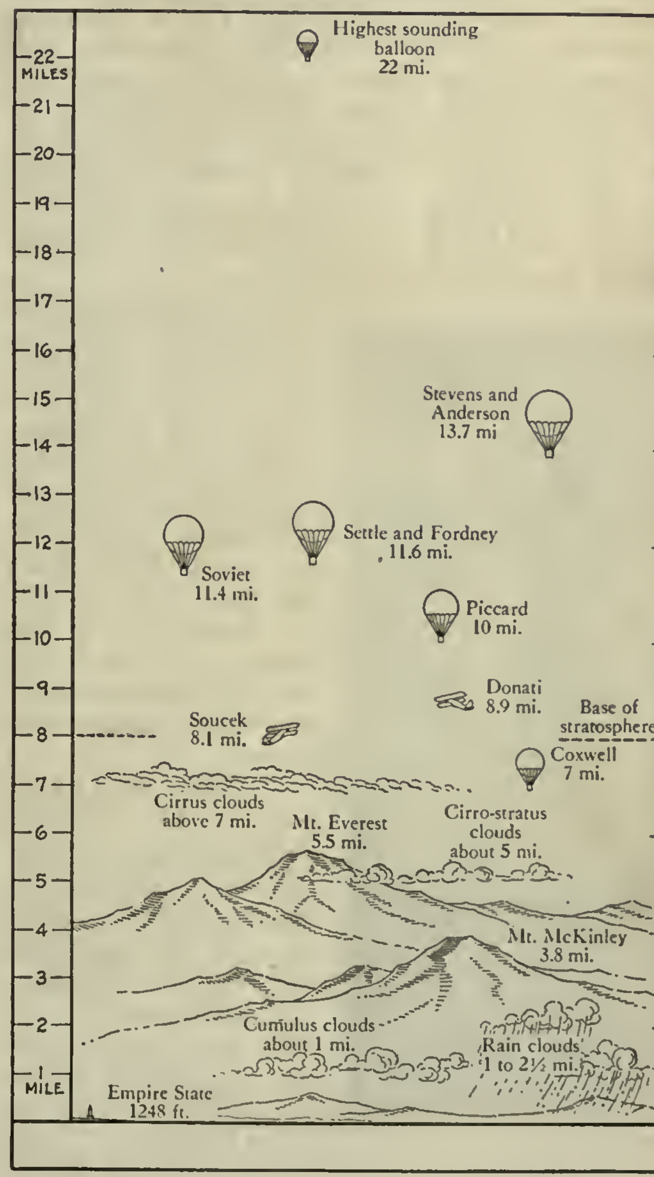


FIG. 6. MAN'S EXPLORATION OF THE STRATOSPHERE

[1] See accompanying workbook, p. 4.

depth is determined by records obtained from small balloons carrying measuring instruments which have risen to this height. As one ascends from the earth toward the top of this vast ocean, the air becomes less and less dense because the higher one goes, the fewer are the layers of air above to press down. If you were to pile up books to a height of two feet, a book near the middle of the stack would be under less pressure than those at the bottom, because there are fewer books above it.

Man has explored this ocean of air in which we live to a height of about eight miles in airplanes and higher in balloons. Study the diagram (Fig. 6) and learn as much as you can about the depth of this air ocean.

Some scientists believe it to be fifty miles in depth and others as much as two hundred miles. Nearly every year attempts are made to establish new altitude records in airplanes and balloons. This is hazardous inasmuch as the upper atmosphere is very cold and the men who fly the planes and balloons must carry oxygen to breathe, because there is not sufficient of this important gas to keep them alive at the great heights attained. In seeking altitude records the planes and balloons must carry sealed instruments which record the height reached and which are later tested by government scientists.

Paul's Photos

FIG. 7. STRATOSPHERE BALLOON

Man has explored the stratosphere. Since the historic flight of Dr. Piccard in 1931 the word stratosphere has become a part of the vocabulary of almost every boy and girl in the country. Do you really know what the stratosphere is? Do you know of what importance it is and why men risk their lives in attempting to explore this region?

Scientists have long recognized that two great layers of air lie above our earth. To the layer which lies next to the earth they have given the name of *troposphere* and to the one above it the name *stratosphere*. The troposphere is the one with which we are most familiar. It is believed to be about twelve miles deep at the equator and about four miles at the poles. The troposphere contains clouds, dust particles, and many tiny living plants known as bacteria. Its temperature is not constant, varying from commonly known earth temperatures to as low as 67 degrees below zero centigrade.

Next above the troposphere and surrounding it is the stratosphere. There are no clouds in the stratosphere, and it is believed that the temperature is constant at about 67 degrees below zero centigrade.

Exploration of the stratosphere was first made by Professor Auguste Piccard in May, 1931. With an assistant he rose about ten miles above the earth. Since that time Professor Piccard has made a second ascent, and several others have reached greater heights. In November, 1935, the Americans Stevens and Anderson made a record ascent from Rapid City, South Dakota, reaching an unofficial height of about 73,000 feet.

All of the stratosphere fliers have used equipment similar to that used first by Piccard. A large, partly inflated balloon is attached to a sealed metal sphere below it, in which the observers and their equipment are carried. Observations are made through windows in the sphere. It is necessary to seal the sphere because there is not a sufficient supply of oxygen in the stratosphere to sustain life. The observers must take tanks of oxygen aloft with them as well as certain chemical substances to absorb the carbon dioxide which they continually exhale into the air of their tiny laboratory.

The great depth of the atmosphere, made up as it is of layers of air, causes the one nearest the earth to be pressed down by the weight of all those above it. Your experiment with the football bladder taught you that even the amount of air that you put in this small space has weight enough to show on the balance. The air over a floor thirty feet square pushes down on the floor with a force of more than nine hundred tons. Just think of that! It hardly seems possible that this gaseous stuff which we call air and which is so light that we do not notice its presence, could possibly weigh so much.

"The pressure of the air" is a common expression, but many do not understand what it really means. When we say that the pressure of air is fifteen pounds per square inch, we mean that if a column of air as deep as the atmosphere and one square inch in cross-section area could be separated, it would weigh fifteen pounds. In other words, on every square inch of surface at sea level air presses fifteen pounds. Of course, as one goes above sea level, up mountains and higher in airplanes and balloons, this pressure gradually decreases. Air pressures at different altitudes are given in the following tabulation:

	Altitude	*Pressure*
Sea level		30 inches of mercury
Mount McKinley	3.8 miles	15 inches of mercury
Mount Everest	5.5 miles	10 inches of mercury
Highest point reached by airplane	8.3 miles	6 inches of mercury
Highest point reached by balloon	over 14 miles	Less than 2 in. of mercury
Highest point reached by sounding balloon	21 miles	Less than 1 in. of mercury

In 1650, Otto von Guericke, mayor of the city of Magdeburg and one of the early experimenters with the pressure of air, built two large hemispheres, 22 inches in diameter. He so constructed these that they could be fitted tightly together and the air exhausted from the inside. When the air had been pumped from within, he found that four teams of horses hitched to each side of the hemispheres were unable to separate them. He demonstrated his experiment before Emperor Ferdinand III.

How can the pressure of air be proved and measured? About the year 1641, Galileo, a great Italian scientist, and his pupil Torricelli, who were among the first to attempt the measurement of the pressure of the atmosphere, noticed that an ordinary lift pump would not work where the water in the well was more than thirty-three feet below the pump. They suggested that perhaps this water column pushed back as much as the atmosphere could push up. Torricelli further suggested that it would be easier to experiment with mercury because it is much heavier, volume for volume, than water, and therefore a shorter column of it would weigh as much as the long column of water. He constructed a tube similar to the one which you used and performed almost the same experiment. He found that a mercury column about thirty inches in length would press just about as much as a column of air as deep as the atmosphere or a column of water thirty-four feet in length.

Tycos
FIG. 8. MERCURY BAROMETER

Water barometers are not generally used because of their size and because of other difficulties. However, several have been built and used, including those made by Blaise Pascal, a French scientist, Von Guericke, a German, and Daniell, an English scientist. To celebrate the three hundredth anniversary of the birth of Torricelli the citizens of his birthplace, Faenza, Italy, erected a monument to his memory in the form of a huge barometer, the largest in the world. The original plans were to make a water barometer, but one containing olive oil was erected instead. A picture of this barometer standing more than thirty-five feet high is shown in Figure 9.

Taylor Instrument Company
FIG. 9. MONUMENT TO TORRICELLI

The aneroid barometer is very different from the mercury column. The word aneroid means "without liquid." The heart of the aneroid barometer is the little shiny box with a wavy surface which you observed in your experiment. If you could remove it from the instrument and study it carefully you would discover that it is a little cylindrical chamber quite hollow on the inside. The box is first constructed as the diagram (Fig. 10) shows, with a metal tube extending from it. Afterward some of the air is removed from the inside of this box and the tube is sealed. The

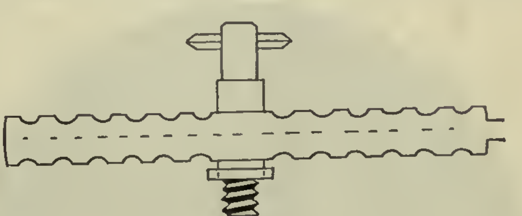


FIG. 10

box therefore has its two sides pushed in because the air pressure on the outside is greater than that on the inside. It then resembles the diagram shown in Figure 11. Now when the pressure of the air changes, the shape of the box changes also. If the pressure increases, the sides of the box are pressed more nearly together, while if it decreases, the sides spring out more nearly straight. When the box is mounted properly this motion of its sides operates a system of levers, which in turn magnify the motion and pass it on to the hand which moves over the scale on the dial. A

commercial aneroid barometer and a view of its working parts are pictured in Figures 4 and 5. Can you find the wavy box, the levers, and the springs?

What are some of the uses of barometers? They find their greatest use in predicting changes in the weather, for it has been found that when the pressure of the air is low we usually have stormy or bad weather, while high pressure usually means fair or

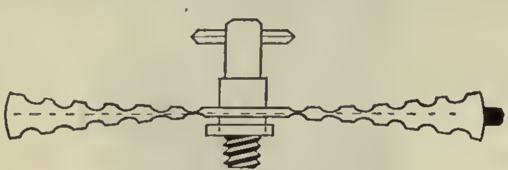


FIG. 11

clear weather. Mercury barometers are generally used where they do not have to be disturbed, as for example, in laboratories, while aneroids, being more easily carried, are used in the office, house, or wherever barometer readings are needed. Aneroid barometers are made in many sizes ranging from the pocket size, used by mountain climbers, up to five or six inches in diameter, used by surveyors and map makers to find the height of a certain point above sea level. When used for these latter purposes the aneroid must be very accurate; in fact, some are made so extremely sensitive that they will show a difference in pressure of one thousandth of an inch of mercury column.

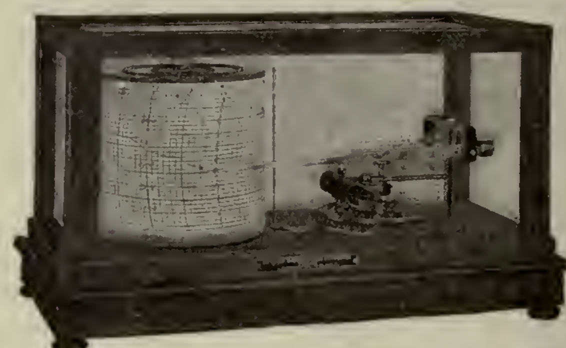
The rapid development of airplanes and dirigibles has greatly increased the use of aneroid barometers, which aviators always include in their equipment. When used in this way the instruments are called altimeters. The scale is made to read in feet of elevation above the earth's surface, making it possible for the pilot to tell his elevation by reading the aneroid on the instrument panel. The picture of an altimeter used in aviation is shown in Figure 12.

Taylor Instrument Company

FIG. 12. ALTIMETER

When records of altitude are sought by aviators or balloonists, a recording aneroid barometer called a barograph is used. This instrument works on the same principle as the ordinary aneroid except that the motion of the little box operates a pen which traces a line in ink on a paper scale. The scale is fastened to a revolving drum which is turned by clockwork.

Barographs are used by weather bureaus and some



Courtesy Taylor Instrument Company

FIG. 13. RECORDING BAROGRAPH

industries where the daily pressure readings are taken and filed away for any future reference. Figure 13 shows a recording barograph.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* pp. 17-26

Clement, Collister, and Thurston, *Our Surroundings,* pp. 37-40

Hunter and Whitman, *My Own Science Problems,* pp. 43-47 and 52-58; *Science in Our World of Progress,* pp. 70-72; *Science in Our Social Life*

Lake, Harley, and Welton, *Exploring the World of Science,* pp. 10-19

Pieper and Beauchamp, *Everyday Problems in Science,* pp. 112-119

Powers, Neuner, and Bruner, *The World Around Us,* Chaps. 8, 9, 10; *This Changing World,* pp. 165-171

Skilling, *Tours through the World of Science,* pp. 75-81

Van Buskirk and Smith, *The Science of Everyday Life,* pp. 7-18

Watkins and Bedell, *General Science for Today,* pp. 1-10 and 19-24

Webb and Beauchamp, *Science by Observation and Experiment,* pp. 223-227 and 233-235

Wood and Carpenter, *Our Environment: Its Relation to Us,* pp. 139-148; *Our Environment: How We Use and Control It,* pp. 94-108

Special References

Jameson, *The Barometer as the Foot-rule of the Air*

Burns, *The Story of Great Inventions*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of how air is weighed.
2. An understanding of why air exerts pressure and how its pressure is measured.
3. An understanding of how the mercury barometer and the aneroid barometer are constructed and how they work.
4. Skill in reading each type of barometer.
5. An understanding of the uses of barometers.

TEST OF MASTERY OF THE TOPIC

This exercise is not a test to be graded but a device to help you discover the things which have not been done thoroughly and which, therefore, need more study. It should be done without any assistance.

Under the heading "Tests of Mastery" in your notebook, complete the following statements, answer the questions, and comply with the instructions.

1. Air exerts ____ because of its ____.
2. Standard air pressure is measured at ____.
3. What is the unit in which air pressure is measured?
4. The atmosphere is thought to be about ____ in depth.
5. A column of mercury ____ high at sea level balances a column of air as high as the ____ is deep.
6. In a mercury barometer the height of the column of mercury is measured from the level in the ____ to the level ____.
7. The basic operating part of the aneroid barometer is a (spring, box) ____ from which (air, water) ____ has been removed.
8. What instrument does an aviator use to tell his altitude?
9. What is the normal atmospheric pressure in pounds per square inch?
10. Who first used mercury as a barometric liquid?
11. Mercury is how many times heavier than water?
12. What is a recording barometer called?
13. Make a diagram showing how the vacuum box of an aneroid barometer is constructed.
14. Man has explored the atmosphere to a height of ____ miles in the airplane and to a height of ____ miles with the sounding balloon.
15. A water column (20, 33) ____ feet high presses as much as a mercury column (20, 30) ____ inches high.
16. When reading a mercury barometer the eye should be on a level with ____.
17. If a single hole is punched in a can of condensed milk or other liquid, the contents do not run out readily. How can the liquid be made to run out more rapidly? Why?
18. Many liquids will not run from small-necked bottles except as bubbles enter. Explain.
19. In the cap of the gasoline tank of an automobile is a very small hole. Can you infer the use of this?
20. Two army officers recently reached a height of about 73,000 feet in a balloon. At this altitude their barometer registered 29 millimeters (a little more than one inch) of mercury as compared with 760 mm. (30 inches) at sea level. What inference would you draw from these data?
21. In making flights into the stratosphere, the huge balloons are only partly filled with gas. Can you infer the reason for this? Predict the effect at a high altitude if the balloon were completely inflated at the earth.

TOPIC 2. SOME DEVICES WHICH USE THE PRESSURE OF AIR

SUGGESTED PROBLEMS AND QUESTIONS

1. How long have pumps been known?
2. What are pumps used for in modern life?
3. How do lift and force pumps work?
4. How does an automobile or bicycle pump work?
5. What is a siphon and how does it work?
6. What are some of the uses of the vacuum?
7. How do we make use of air pressure in breathing?

SUGGESTIONS AND HELPS FOR STUDY

Refer to "Suggestions and Helps for Study," p. 1.

In the study of this topic certain words which you should know will be met for the first time. Study them carefully and refer to them frequently that they may become a part of your vocabulary.

piston—a closely fitting plug in a cylindrical chamber so constructed that it will move back and forth.

siphon—a tube through which liquids are moved from high levels to low levels by means of air pressure.

suction—the act of drawing a substance in one direction by means of unequal pressure. If pressure from one side is reduced, the object is moved in that direction by the force on the other side.

vacuum—a space which contains no air or other substance.

valve—a device used to close and open small passages.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 5. How is a lift pump constructed and how does it work?

Secure a commercial kitchen lift pump and unbolt the bottom section with a wrench. The top may be removed by loosening the set screw which holds it. Examine the valve at the bottom and the valve in the piston or plunger. Reassemble the pump and study its operation by pumping water with it. If a glass model lift pump is available, study the action of the valves. A glass model lift pump may be constructed as shown in the diagram (Fig. 14). The cylinder is a straight-sided lamp chimney. The piston is a two-hole rubber stopper; attached to it by a brass thumb tack is a valve flap made of leather to cover one hole. The base is a one-hole rubber stopper with a leather flap for the foot valve. The handle may be of wood, or a brass rod may be inserted in the other hole of the piston stopper.

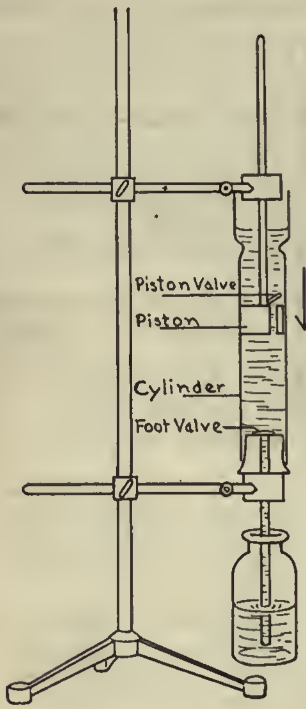


FIG. 14

In your notebook[1] record the notes of this experiment and complete the statements below.

On the up stroke the piston valve is (open, closed) ____ and the foot valve is ____. The pressure on the surface of the water in the jar or well is ____ per square inch. As the piston rises, the pressure in the cylinder is ____, thus allowing the ____ on the water in the jar or well to ____.

Copy the drawing shown in Figure 15 and place the valves as they would appear on the down stroke of the piston.

Experiment 6. What causes a siphon to work?

Connect two pieces of glass tubing about ten inches in length with a twelve-inch section of rubber tubing to form a siphon. Fill the siphon with water and pinch the rubber at the top while you insert each glass tube in a bottle of water as shown in Figure 16. Grasp one bottle in each hand and by shifting the levels of the bottles study the action of the siphon.

Record the notes of this experiment in your notebook[2] and write the completions of the statements given below.


FIG. 15

The siphon does not flow when the bottles are ____. The water always flows from the ____ level to the ____ level. The pressure of the air on the water in each bottle is ____ pounds per square inch. The water in the ____ arm of the siphon weighs the more. This causes the water always to flow ____ the short arm and ____ the long arm. The liquid in the siphon may be made to run faster by ____.

Experiment 7. How is a bicycle pump constructed?

Secure a bicycle or automobile tire pump and take it apart. Study the construction of the piston carefully.

In your notebook[3] make a cross section drawing showing the construction of the pump, record the notes of the experiment, and complete the statements below.

The air gets into the pump through ____. The piston is made airtight by means of a ____ which presses tightly against the walls of the cylinder on the ____ of the piston but allows the air to ____ on the ____ stroke.

Experiment 8. How does air get into the lungs?

Close the top end of a lantern globe tightly with a stopper cut from beaver board. Through the stopper drill a small hole for a piece of glass tubing about six inches in length. To one end of the glass tube attach a toy balloon by winding the neck with many turns of thread. This connection should be airtight. Place the glass tube through the hole in the stopper in such a way that the balloon will hang inside the lantern globe. Now stretch a piece of toy balloon or old auto tire inner tube tightly over the bottom of the globe and secure it with string. The lantern globe represents the upper chest cavity, the balloon a lung, and the rubber across the bottom the diaphragm. Push the diaphragm up into the chest cavity. Pull the rubber diaphragm down.

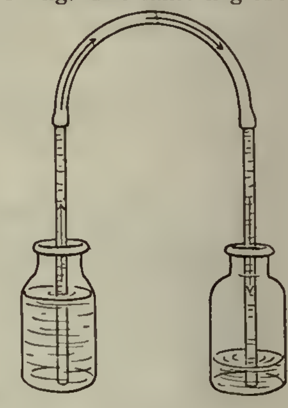


FIG. 16

In your notebook, record the notes of this experiment and complete the statements given below.

When the diaphragm is expanded the ____ in the lower chest cavity is reduced and ____ is forced into the ____. Exhaling is accomplished by ____ the diaphragm when air is forced ____ of the ____.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. In your notebook list as many uses of the vacuum as you can and explain how each is applied.
2. Make an investigation of the construction and operation of a vacuum cleaner and record the notes in your notebook.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How long have pumps been known? Mention of them is found in the writings of the ancient Greeks, several hundred years before the birth of Christ. The force pump was probably invented by Ctesibius, a Greek, who lived in the city of Alexandria in Egypt. This pump was used in quenching fires; modern fire fighting apparatus has a history. During the Middle Ages pumps were in common use for raising water from wells and from rivers for purposes of irrigation and general use. In fact, it was by observing a pump that Galileo, an Italian scientist, was led to the discovery of the barometer. He noticed that a lift pump could not be used if the well was much more than thirty feet deep.

What are pumps used for in modern life? They are used on the farm and in small towns for securing water from wells. In many cities the provision of an adequate supply of water would be impossible if pumps were not used. Industries use them for pumping water or other liquids such as the brine in refrigerating

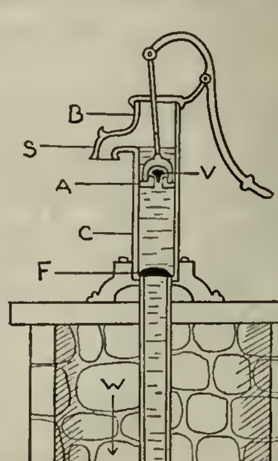


FIG. 17. LIFT PUMP

[1] See accompanying workbook, p. 5.
[2] See accompanying workbook, p. 5.
[3] See accompanying workbook, p. 6.

plants. Many fire engines are equipped with force pumps that make it possible to fight fires in high buildings.

How do lift and force pumps work? The experiment has taught you that as the piston *A* of the lift pump in Figure 17 moves upward, the pressure in the cylinder under it will be lowered below that of the atmosphere pressing on the water in the well *W*. This greater pressure on the surface of the water in the well will push some of the water up into the cylinder *C* of the pump, forcing the foot valve *F* open as it enters. On the down stroke of the piston, valve *F*

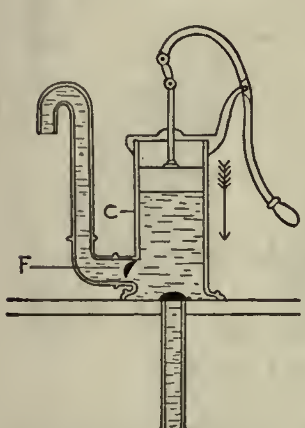


FIG. 18. SIMPLE FORCE PUMP

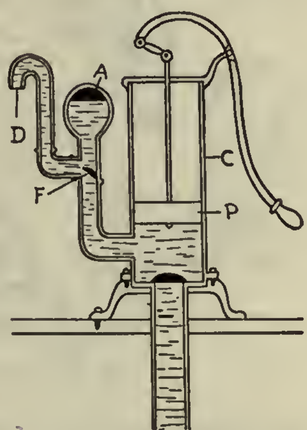


FIG. 19. AIR DOME FORCE PUMP

will close, preventing the water from running back into the well. The piston valve *V* will be forced open as it pushes against the water in the cylinder and will allow much of it to pass into the upper part of the cylinder *B*. On the next up stroke of the piston this water will be raised to where it can run out of spout *S* while at the same time more water from the well is being pushed past the valve *F*. The foot valve *F*, which is made of leather, often dries out, as does the leather part of the piston. This prevents the reduction of pressure under the piston until the pump is "primed" by pouring water into the top, thus moistening the leather parts.

The simplest kind of force pump differs from the lift pump only by lacking the valve in the piston and in having an opening in the bottom of the cylinder which is closed by valve *F* as shown in Figure 18. This valve opens outward. When the piston goes up, water is pushed from the well past the foot valve into the cylinder *C* of the pump. This is exactly the same as the lift pump. When the piston goes down, the water in the cylinder is forced through the valve *F* and delivered through a pipe to an upper floor. This simple force pump delivers water only on the down stroke of the piston, thus causing the liquid to spurt out of the opening in jerks. This is not desirable; for example, in fighting fires if the water came only in spurts it would prove of little use. It is possible to secure an even flow of water from a force pump by adding a very simple part to the one described above. An air dome is placed in the delivery pipe and the water comes in a steady stream. The water gets into the cylinder *C* (Fig. 19) just as in the lift pump and simple force pump. It is also forced out of the cylinder on the down stroke of the piston *P*. As it leaves the cylinder *C* it forces valve *F* open and enters the air dome or chamber *A*. The air is compressed as the water enters and acts as a cushion or spring. During this stroke water is also forced out of the opening *D*. As the piston begins its up stroke the pressure is removed from the air in the dome and it tends to expand as does a spring which has been coiled under force. It pushes against the water in the chamber *A*; since the water cannot get past valve *F* it is pushed out of the spout at *D*. You will see then that on the down stroke of the piston water is pushed out of the spout by the force of the piston while on the up stroke it is pushed out by the force of the expanding air in the air chamber. This makes an even flow on both strokes of the piston. Have you ever noticed the air dome on a fire engine force pump or on a pump about the farm?

How does an automobile or bicycle pump work? In the early days of the automobile one of the most important tools in the tool box was the tire pump. It was almost as common to see people stranded by the side of the road mending and pumping up a tire as it was to see them motoring along. This has changed, thanks to the improvements which have been made in the quality of tires. The air pump, nevertheless, is still an important part of automobile equipment and is carried by almost every motorist. While bicycles are not so common as they were at one time, they still must use compressed air in their tires, and one of the simplest ways of getting it is with the hand air pump.

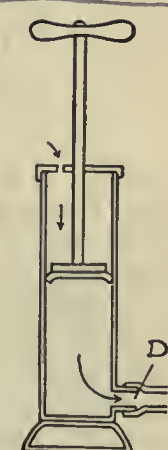


FIG. 20. CROSS SECTION OF BICYCLE PUMP

This pump is interesting in its construction and operation. It has a cylinder enclosing a piston which moves up and down inside. This piston is a flexible leather circle cut a little larger than the cylinder. This allows the air to get past the piston on the up stroke but prevents it from doing so on the down stroke as the leather then is forced tightly against the cylinder walls by the air which is below it. This air is compressed as the piston comes down and is forced from the delivery hose past the opening *D*. The tire valve prevents the air in a tire from escaping back into the pump.

Siphons find many uses in modern life. Aquariums, wash tubs, barrels, and other containers that are difficult to move may be emptied by them. They are used in the operation of the trap beneath sinks and wash bowls and also in the operation of toilet bowls. When New York City built its great water supply it was necessary to get the water from the west to the east side of the Hudson River. After studying the situation the engineers decided that a huge siphon tunnel upside down running far below the river would solve the problem, and so they tunneled down and across the river and then up toward the surface on the other side, hundreds of feet through solid rock, to make one of the largest siphons in the world. The city of Los Angeles found that its water supply must be taken over a mountain, and so a great siphon was used to accomplish this feat.

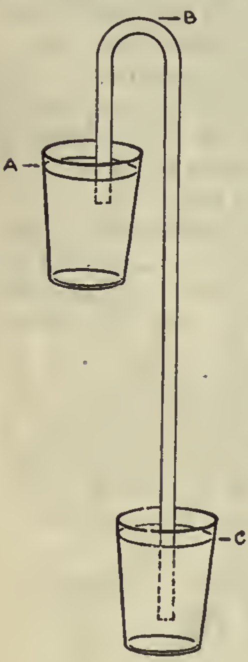


FIG. 21. SIPHON

What is a siphon and how does it work? In the experiment which was performed with the siphon you learned that liquids may be moved from one level to a lower one only, and that the siphon tube must first be filled with liquid. The reason for this is interesting. If the glasses in Figure 16 were at the same level, no water would flow because the liquid in each tube of the siphon would weigh the same and therefore they would counterbalance each other. In the diagram (Fig. 21), glass *C* has been lowered until the long arm *BC* of the siphon is about three times as long as the short arm *AB*. Since the weight of the water in tube *BC* is much greater than that of the water in tube *AB*, the flow starts toward *C*. Air pressure pushing down on the water in glass *A* will push more water up into the tube, and the action continues until the water reaches the end of the tube. It is interesting to note that several different types of self-starting siphons can be made to work very well.

What are some of the uses of the vacuum? Many years ago Galileo and his associates offered the theory, "Nature dislikes a vacuum," to explain the fact that water rushes into the cylinder of a lift pump from a well. In our modern life we seem to have found so many uses for the vacuum that we do not worry about whether nature likes it or not. A study of Figure 22 will show you how common it is in our everyday experience. Can you add other uses to those pictured?

A vacuum is simply a space from which air and other substances have been removed. The pressure in a vacuum space is decreased as more and more of the air is removed. If a barometer tube were placed in such a space it would gradually fall as the pumping is continued. Recall that when the pressure is 15 pounds per square inch, a mercury column stands 30 inches high. Vacuums can be produced in which the mercury column would be less than the hundredth part of an inch in height.

High vacuums are important in many branches of science and have become increasingly important with

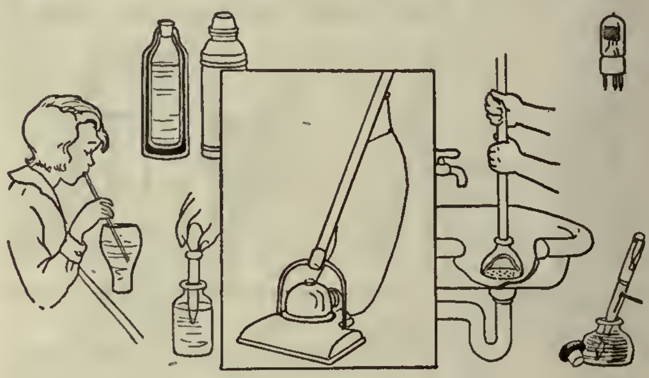


FIG. 22. USES OF THE VACUUM

the development of radio and X-ray tubes. High vacuums are secured by means of different types of pumps that are made to remove practically all the air from a tube or bulb.

Variations in air pressure are used in the vacuum sweeper. It is commonly believed that a vacuum sweeper operates through the suction of a vacuum. While it is true that the whirling pump fan in a vacuum cleaner produces a partial vacuum in the nozzle or part which touches the carpet, the real force which gets the dust and dirt out of the meshes of the rug is furnished by the pressure of the air. When the fan starts to turn, the pressure back of it is increased because air is forced or pushed by it into the bag. That the pressure in the bag is increased may be seen by the fact that the bag fills out at once. The pressure just in front of the fan is considerably decreased, and as the outside air under greater pressure rushes in through the nozzle, it takes dust and dirt particles with it.

Atomizers and sprays make use of air pressure. Perfume is often applied with an atomizer, and frequently sore throat is treated with a spray. Each of these devices operates with air pressure. When the bulb is pressed, a blast of air is blown past the small pipe which dips into the liquid in the glass container. This reduces the pressure in the pipe, and the greater pressure of air over the liquid pushes some of it up into the blast where it is atomized or broken up into a spray.

How do we make use of air pressure in breathing? The human body is in many respects like an engine. It must have fuel upon which to run, and the fuel must be burned in order that its energy may be released. Burning requires oxygen, which must be supplied to the fuel in that portion of the body where the energy is being released. Air contains oxygen which is taken into the body through the lungs and there is taken up by the blood and distributed to the various parts of the body.

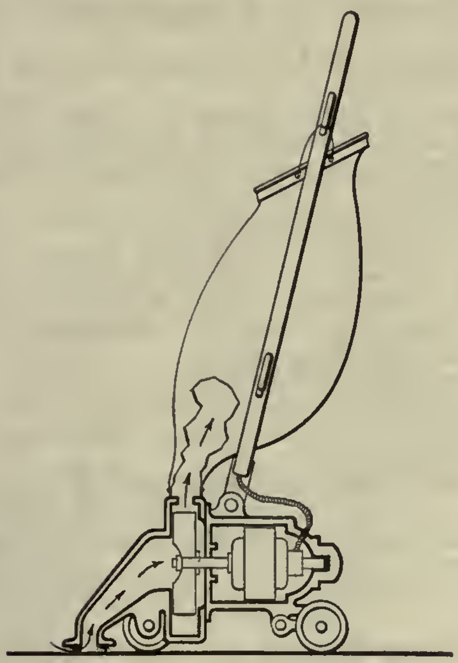


FIG. 23. VACUUM SWEEPER

The lungs are two great sacs filling most of the upper chest cavity. They are connected with the outside air by the windpipe. In the lungs the air tubes divide, always getting smaller like the branches of a tree. The lungs are in the upper part of the body cavity, which is divided into two parts by a muscular tissue called the diaphragm. This was represented by the tightly stretched rubber at the bottom of the lantern globe in your experiment. When the breast bone is lowered the diaphragm collapses as shown at *B* in Figure 24. This tends to decrease the size of the body cavity and force the air from the lungs. As the breast bone is raised as shown at *A* the diaphragm straightens, slightly enlarging the cavity. The enlargment slightly decreases the pressure in the cavity, and air rushes into the lungs to fill them. This action goes on automatically about eighteen times a minute.

Deep breathing is desirable, for when we exhale naturally only about one seventh of the air contained in the lungs is breathed out. This leaves much unchanged air in the lungs unless deep breathing forces it out and allows a fresh supply to enter.

REFERENCES FOR FURTHER STUDY

Caldwell and Curtis, *Science for Today*, pp. 40-47

Clement, Collister, and Thurston, *Our Surroundings*, p. 41

Hunter and Whitman, *My Own Science Problems*, pp. 59-66; *Science in Our Social Life*, pp. 49-75

Lake, Harley, and Welton, *Exploring the World of Science*, pp. 24-32

Pieper and Beauchamp, *Everyday Problems in Science*, pp. 482-485

Powers, Neuner, and Bruner, *The World Around Us*, Chap. 9

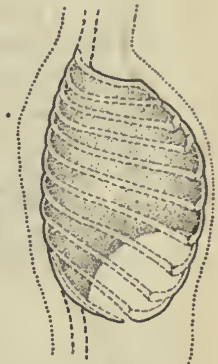
Van Buskirk and Smith, *The Science of Everyday Life*, pp. 18-23

Watkins and Bedell, *General Science for Today*, pp. 11-19

Wood and Carpenter, *Our Environment: How We Use and Control It*, pp. 108-118

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the construction, operation, and importance of lift pumps.
2. Ability to replace the worn valves of a lift pump.
3. A knowledge of how air pressure is related to the operation of pumps and siphons.
4. Ability to start and use a siphon in real situations.
5. Knowledge of the construction and operation of an air pump.
6. Ability to care for an air pump.
7. A knowledge of the uses and importance of the vacuum.
8. A knowledge of the importance of air pressure in breathing.



A

B

FIG 24. HOW WE BREATHE

TEST OF MASTERY OF THE TOPIC

In your notebook complete the following statements, answer the questions, and comply with the instructions.

1. On the up stroke of a lift pump the ____ valve is closed.
2. The pressure of the atmosphere will hold up a water column ____ feet high.
3. Water rises into the cylinder of a lift pump because the pressure in the cylinder is ____ than ____ pressure.
4. On the (up, down) ____ stroke of the piston in a lift pump the foot valve is closed.
5. The force pump differs in one way from the lift pump by not having ____ in the piston.
6. Is the pressure in a vacuum greater or less than atmospheric pressure?
7. To start a siphon the tube must be ____ with liquid.
8. The ordinary bicycle or automobile pump has a (leather, brass) ____ piston.
9. The force pump can raise water to a greater height

than a lift pump because of the ____ developed in the air dome.

10. The siphon operates because of unequal ____ caused by unequal lengths of the ____.

11. Which of the following devices in some way make use of a vacuum or partial vacuum?
Automobile gasoline line, air brake, sink opener, can opener, lift pump, electric light bulb, rubber heels, automobile cylinder, automobile windshield wiper, electric flatiron, some types of washing machines

12. Which two of the words or phrases after the dash are most closely associated with the key word before it?

a. vacuum—vacuole, varicose, reduced pressure, increased pressure, lift pump

b. siphon—lower level, air pressure, vacuum, valve, vertical

13. Air enters the lungs because the ____ is decreased by ____ of the ____.

14. Figure 25 is the diagram of a double acting force pump; from your knowledge of force pumps explain how this one operates and state its advantages over the common force pump.

15. A farmer, after driving a well, attached a lift pump to the pipe and found that it would not pump the water which he was sure he had struck. In driving the well he had used six-foot lengths of pipe. Cite the possible causes of the failure of the pump to work and show how you would proceed to locate the actual cause.

16. Dirt and dust are pushed into the nozzle of a vacuum cleaner. Choose from the following group of statements those which would be important in establishing the truth of the statement above.

(a) The vacuum sweeper will not pick up heavy objects.

(b) Air blows through the fine meshes of the bag.

(c) The sweeper works better on rugs than on floors.

(d) It is difficult to pick up bits of paper with a vacuum sweeper.

(e) The bag of the sweeper bulges out when the motor is running.

(f) The motor turns a fan.

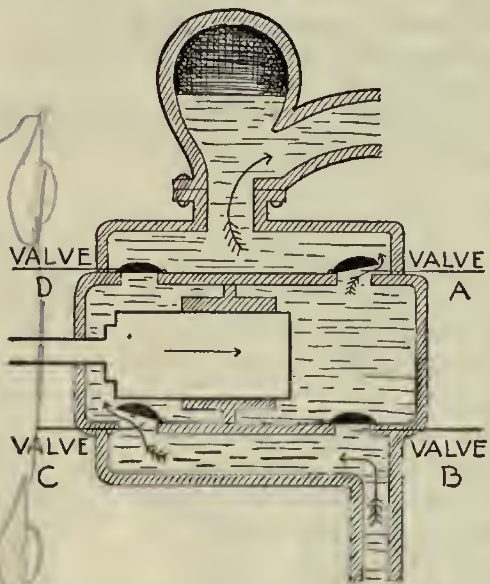


FIG. 25

TOPIC 3. MAN'S USE OF COMPRESSED AIR

SUGGESTED PROBLEMS AND QUESTIONS

1. **What are some of the modern devices that use compressed air?**
2. **How does compressed air enable men to work under water?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems suggested above until you are thoroughly familiar with them; then begin their solution by doing the experiments and readings suggested below. Follow the same plan used in the two previous topics. Refer to it and review it carefully before beginning.

If the problems of this topic appeal to you, you will find fascinating reading in the special references that are listed on pages 26 and 27.

2. Master the meaning of the following new words which you may find in this study:

caisson—a large hollow cylinder made of steel and open at the bottom, used to enable men to work at the bottom of a river or other body of water.

gauge—a device for measuring steam, gas, or water pressure.

piston—a sliding cylinder fitting inside another cylinder along which it moves; used in steam, gas, and oil engines.

energy—the ability to do work.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 9. How can a model caisson be made?

Place a glass funnel in a pan of water as illustrated in Figure 26. Attach a short length of rubber tube to the stem of the funnel and increase the air pressure on the inside by blowing through the tube. Float a cork or small piece of wood under the funnel and repeat the experiment. When the pressure has been increased, close the tube with a clamp or a string.

In your notebook[1] record the notes of this experiment and complete the following statements.

FIG. 26

[1] See accompanying workbook, p. 7.

As the pressure on the inside of a caisson is increased, the water level inside ____. All water may be removed if sufficient ____ is applied. To keep the water from entering the caisson a pressure (greater, less) ____ than the pressure tending to force water in must be maintained.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

Take apart a compressed-air door stop and study its construction.

Visit a service station or garage and study the construction of an air compressor.

Measure the air pressure in the tires of an automobile.

Study the operation of the air brakes on a street car or bus.

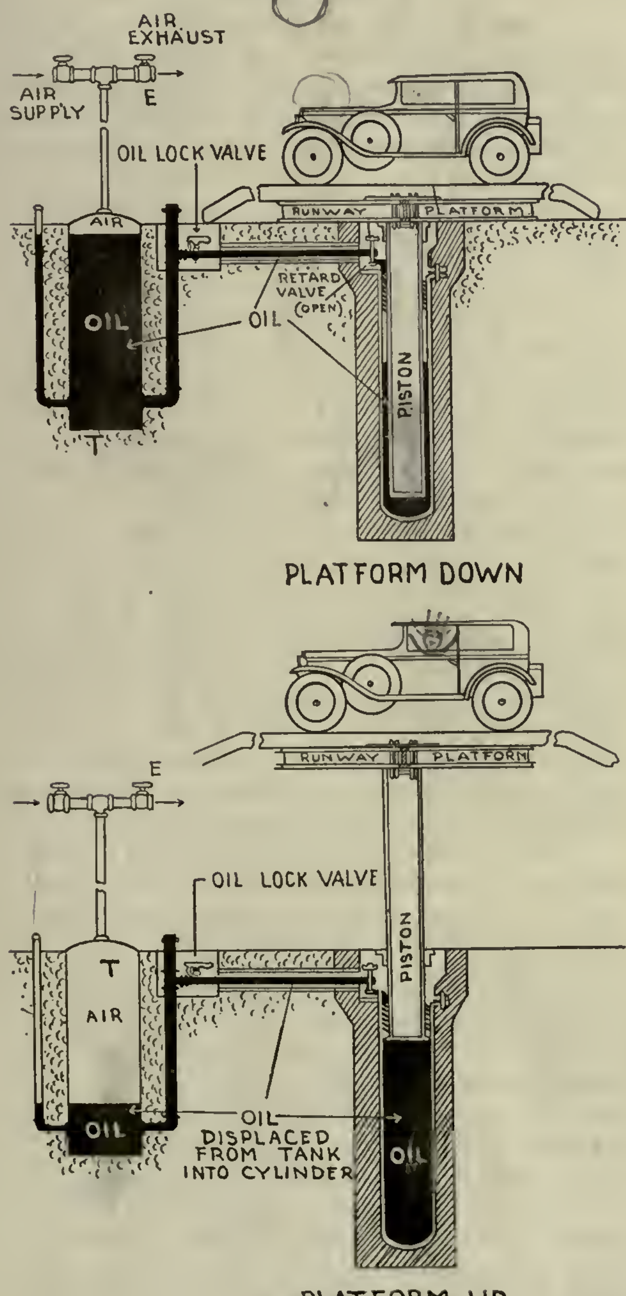


FIG. 27

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What are some of the modern devices that use compressed air? Many of our largest buildings, our great bridges, and our dams were built much more easily and quickly because man has learned how to compress air and then to use its great "spring," as it was once called by Robert Boyle, an Irish scientist. Compressed air is used on many of our modern transportation devices such as buses, street cars, and trains, for operating the brakes, thus making our travel much safer.

Have you ever noticed the large lifts that are used at oil stations to raise automobiles from the ground that greasing the under parts may be made easier? Many of these are operated by compressed air which pushes on oil and raises the piston and platform. When the air is released by opening the exhaust valve *E* (Fig. 27), the weight of the car and piston pushes the oil back into the tank *T*.

If there is such a lift near your home, you will find it interesting to study. No doubt you will find, inside the filling station, the compressor which supplies the air both for the lift and for tires. If you study it carefully you will see that it has a piston which is driven in a cylinder by an electric motor. Air is taken into the cylinder through a valve and is then compressed when the piston pushes it into the storage tank. The compressor is automatic. When the pressure reduces to a certain point as air is used, an electric switch which starts the motor is closed, and the pressure is again built up inside the storage tank.

Compressed air is used in hammers, riveters, and drills. Study the cross section diagram in Figure 27

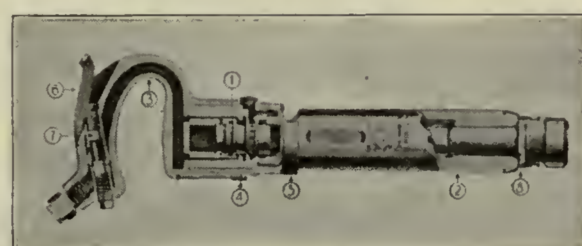


FIG. 28 COMPRESSED AIR HAMMER

1. Cylindrical valve. 2. Cylinder threaded into handle. 4. Locking ring preventing handle from loosening. 5. Exhaust deflector. 6. Trigger control. 7. Throttle valve. 8. Spring clip set retainer.

and see if you can explain how the compressed air drives the piston back and forth. Air comes in first on one side of the piston and then on the other, causing the piston to move rapidly back and forth. When the piston is made to strike against a tool such as a drill or a hammer, many powerful blows can be struck in a short time. The compressed air is controlled by a

valve worked much as the trigger on a gun.

Compressed air is used in spraying many substances. The most modern way to apply paint and varnish is by means of a compressed air spray. Nearly the same type of spray is used for spraying fruit trees to protect them from pests. Pressure is first built up in a tank by means of a pump and then is released in such a way that it carries with it an atomized spray of the liquid being applied. Such sprays operate in much the same manner as the common household spray used for killing flies and mosquitoes.

Compressed air is used in diving suits and deep-sea work. Divers who work far below the surface of the water must be supplied with air for breathing and to help them withstand the tremendous pressure caused by the water. Diving suits are equipped with a hose through which compressed air is forced.

Compressed air is used to transport parcels. In many cities mail is sent from one station to another by means of compressed air. The device is similiar to the cash transporting systems used in many large department stores. The material to be sent is placed in a container, usually made of leather, which fits tightly into a tube carrying a blast of air. The container acts much as a piston; the pressure increases behind it and pushes it along.

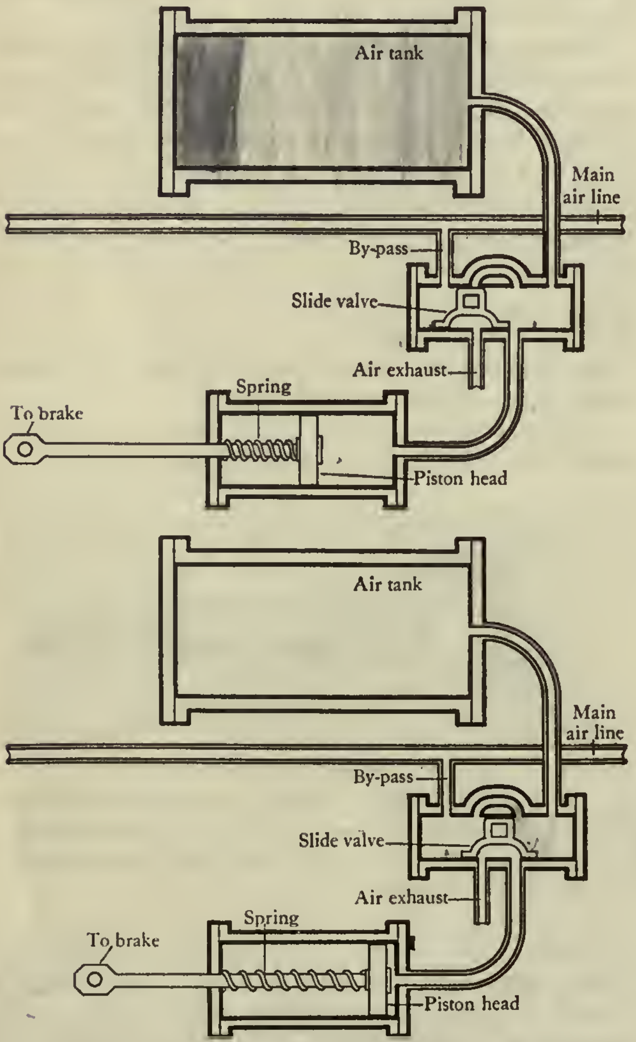


FIG. 29. AIR BRAKE

Note the changed positions of the slide valve and the piston head in the lower diagram.

Compressed air is used in the air brake. Before 1868, all trains were stopped by means of hand brakes. George Westinghouse, then a young man, saw one of the many accidents of the period and determined to improve on the old hand brakes. In 1868 the first train to be equipped with air brakes was run between Pittburgh, Pennsylvania, and Steubenville, Ohio. Since that time not only steam trains but electric trains, street cars, and buses have adopted it for use.

In the operation of the airbrake, air is compressed in a compressor either by steam, electric motor, or gas engine, to a pressure of seventy or eighty pounds per square inch. From a central tank in the engine compressed air is distributed the entire length of the train by means of pipes and hose connections between the cars. Beneath each car is a brake cylinder and reservoir. The cylinder contains a piston which may be moved by the pressure in the reservoir. When the brakes are to be applied, the engineer pushes a lever to a certain position, thus reducing the pressure in the pipes which come from the engine. Through a valve arrangement the higher pressure in the reservoir under the car is released and the piston is moved. This motion is transmitted through levers which cause the brake shoes to press against the wheels. When the brakes are to be released, the engineer moves the lever in the engine to another position thus causing the pressure in the pipes to increase. When this pressure is equal to that in the car reservoir, a spring pushes the piston back, thus releasing the brake shoes from the wheels.

All these devices are able to aid man because air which has been compressed has a great deal of energy and can do work when the pressure is released and the air expands to its original volume.

How does compressed air enable men to work under water? The building of bridge foundations and tunnels which go under water frequently makes work at the bottom of the river necessary. The caisson is a large hollow steel case open at the bottom end. Air can be forced into such a chamber under enough pressure to keep the mud and water out and allow men to work with pick and shovel digging down to bed rock where the foundation may rest firmly. Figure 30 will teach you many interesting things about work in a caisson. Notice how the gravel and dirt are raised to the top without letting the air out. The pressure in

the lowest level of the caisson is frequently thirty pounds per square inch and sometimes may have to be increased to forty-five or fifty pounds.

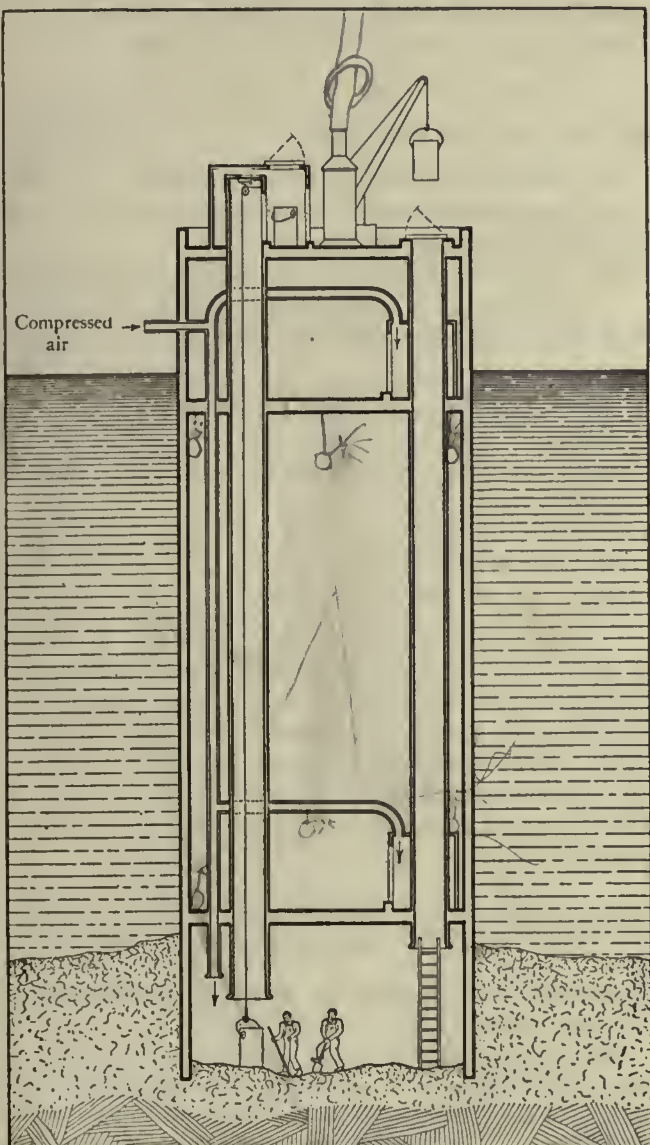


FIG. 30. MEN AT WORK IN A CAISSON

Men who must work in caissons sometimes suffer from a peculiar ailment called "caisson disease" or "the bends." This used to cause many deaths among the workers until it was found that it was caused by changing too quickly from the greater pressure in the caisson to atmospheric pressure. Modern safeguards provide a gradual change from one pressure to another. A study of Figure 30 will show you how this is accomplished.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, pp. 47-53

Clement, Collister, and Thurston, *Our Surroundings*, pp. 41-42

Hunter and Whitman, *Science in Our World of Progress*, pp. 53-57

Lake, Harley, and Welton, *Exploring the World of Science*, pp. 32-37

Pieper and Beauchamp, *Everyday Problems in Science*, pp. 485-489

Powers, Neuner, and Bruner, *The World Around Us*, Chap. 8

Van Buskirk and Smith, *The Science of Everyday Life*, pp. 30-31

Watkins and Bedell, *General Science for Today*, pp. 11-19

Wood and Carpenter, *Our Environment: How We Use and Control It*, pp. 118-122

Special References

Corbin, *Romance of Submarine Engineering*

Darrow, *Masters of Science and Invention*

Fraser, *The Story of Engineering in America*

Bond, *With the Men Who Do Things*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the construction and operation of the caisson in the building of bridges, tunnels, and dams.
2. A knowledge of the uses made of compressed air in drills, sprays, sand blasts, and other devices.

TEST OF MASTERY OF THE TOPIC

In your notebook answer the following questions and comply with the instructions.

1. What pressure is usually maintained in the balloon type automobile tires?
2. What is the device which measures this pressure called?
3. Explain the principle of the caisson.
4. Make a section drawing of some devices which you have studied that makes use of compressed air, such as a drill, hammer, or perfume spray.
5. What did George Westinghouse do of importance in connection with this study?
6. What causes the disease known as "the bends"?
7. Write a short account of some undertaking of which you have read where compressed air played an important part.
8. Make a sectional drawing showing how a caisson is used.
9. Which of the following experiences have you had? In which of the experiences in the list may you find use for the knowledge gained in this study?
   - The use of air brakes on a bus, trolley, or train
   - The use of compressed air in lifts
   - The use of compressed air in painting
   - The use of compressed air in automobile tires
   - The use of compressed air in spraying the nose or throat
   - The use of compressed air in building a bridge or tunnel
   - The use of compressed air in operating a drill
   - The use of compressed air in operating a riveting hammer
10. On the basis of the facts learned in this topic, infer what causes the hissing sound as the engineer of a train applies the air brakes.

11. Refer to the diagram in Experiment 9. From the following statements choose the ones which may be causes of the cork's going to the bottom of the dish.

(a) The water pressure was greater than the air pressure.

(b) The air pressure was greater than the water pressure.

(c) The cork will not float in air.

(d) Air and water can not occupy the same spacc at the same time.

12. Compressed air makes possible many of our athletic games such as basketball, football, soccer, and tennis. Explain how this is true.

TOPIC 4. THE RELATION OF AIR TO SOUND

SUGGESTED PROBLEMS AND QUESTIONS

1. **How does sound affect our daily lives?**
2. **What is sound and how does it travel?**
3. **What is the nature of musical tones?**
4. **How is the human ear constructed for hearing?**
5. **How may different tones be produced on musical instruments?**
6. **How does the phonograph reproduce sound?**

SUGGESTIONS AND HELPS FOR STUDY

1. Try to find the answers to the following questions in solving the problems above. Some can be answered by the experiments, others by the reference readings.

a. Answer these questions about problems 1, 2, and 3.

1) In what ways may sound be produced?

2) How fast does sound travel?

3) Does it travel through all substances?

This may be answered when you have performed Experiment 11.

4) What makes a siren screech?

5) What is the difference between a noise and a musical tone?

b. Answer these questions to solve problem 4 above.

1) What are the parts of the human ear?

2) What is the duty of each part in producing the sensation of sound?

3) What are the causes of deafness?

4) What are the highest and lowest numbers of vibrations which can be heard by the human ear? See Experiment 12.

c. Answer these questions about problems 5 and 6 above.

1) How are phonograph records made?

2) What difference is noticed when a phonograph record runs slowly and when it runs fast? This may be answered by experiment.

3) How does a phonograph record appear when looked at under a magnifying glass?

4) How is a phonograph constructed?

5) How are different tones produced on a violin or other stringed instrument?

6) How are different tones produced on a trombone or other wind instrument? Experiment.

2. You may find the following new words and phrases in this study:

compression—the pushing or squeezing together of a substance.

diaphragm—a thin membrane or disk which may vibrate.

pitch—Two musical tones are said to have difference of pitch if they differ in the number of vibrations made per second. A low or bass tone has few vibrations per second and hence a low pitch. A high or soprano tone has a greater number of vibrations per second and a higher pitch.

quality—The quality of a musical tone enables one to tell a difference between the same tone sounded on a piano and a cornet.

vibration—a movement to and fro as one vibration of a violin string.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 10. How may sound be produced and what causes it?

Vibrate rods of metal held in a clamp or vise by stroking with a cloth dipped in rosin. Vibrate air columns in bottles and flasks by blowing across them. Vibrate strings. Strike a tuning fork on a rubber stopper and touch the tines to water in a glass. Place little paper riders on a stretched violin string and pluck it.

Record the notes and results of this experiment in your notebook.[1]

Experiment 11. What substances transmit sound?

Use a tuning fork as a sounding body and transmit its sound to a blackboard, door, or table top through as many different substances as you can. The following are suggested: wood, cardboard, felt, string, wire, iron rod, brass rod, water, wood alcohol. In the case of liquids paste a disk of wood or cardboard to the bottom end of the tuning fork and rest this against the surface of the liquid in a glass.

In your notebook[2] record the results of this experiment and list the substances which you found to transmit waves.

[1] See accompanying workbook, p. 8.

[2] See accompanying workbook, p. 8.

Experiment 12. How high a tone can the ear distinguish?

Test the upper limit of hearing by use of a Galton's whistle which you can borrow from the physics department of your school or by cutting short lengths of iron rod and suspending them with string in such a manner that they may be sounded with a small hammer. The shorter the length, the higher the pitch. Who has the highest limit of hearing in your class?

In your notebook[1] record the results of this experiment.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Secure an old phonograph and take the sound reproducing mechanism apart.
2. Study a phonograph record under the microscope.
3. Make a collection of bottles and pipes of varying pitch.
4. Study several musical instruments, some string and some wind, and see how various tones are produced.
5. Measure the speed of sound in air. Have one person go away a measured distance of at least a half mile and shoot a blank cartridge from a gun. Time the difference between the flash and the instant the sound reaches you. A stop watch will be found useful for this.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How does sound affect our daily lives? We live in a world of shakes and quivers. Nearly everything that we do starts something moving or quivering. If we walk across the floor, it moves; if we speak, the air about us is disturbed and begins to move. It is very easy to set the air moving because it is a gas and touches almost everything. When the ocean moves, it stirs the air above it; an animal stealing noiselessly through the forest moves the air about him.

So noisy have some of our great cities become with the clang of metal on metal, the auto horns, and the fire sirens, that in many places steps are being taken to measure the noise and to make laws that at certain points in the city near hospitals and schools, it must be kept below a certain point. Perhaps our policemen will soon be carrying sound-measuring devices in their pockets.

In spite of all the noise there is also a beauty in sound. What a drab and uninteresting world this would be if it were not for music. Even though not educated to it, all have a love for the enjoyment that only music can give.

FIG. 31

[1] See accompanying workbook, p. 8.

We live in this world of horrid and beautiful sounds where each air disturbance is carried along hither and yon as if it were the only one there, some to die out unheard when they have spent their energy, others to fall upon an ear of some lower animal or man and there, through that marvelous mechanism, to be changed into a nerve current, carried to a brain, and recognized as noise or music.

What is sound and how does it travel? If a rubber band, string, or metal rod is vibrated, if a tight skin is hit as in a drum, or if one blows across the mouth of a bottle, setting the air in motion, sound waves are set up in the air around and travel away from the center of the disturbance in every direction as shown by the illustration in Figure 31. Figure 32 shows some common sources of sound waves.

FIG. 32

If you have ever thrown a stone into a still pond and noticed the waves as they spread over the water, you have a picture of how sound travels; we must remember, however, that it will go upward and downward as well. To a certain extent it will travel through almost anything. Have you ever put your ear to a railroad rail to see whether a train was coming or heard some one cracking stones under water when you were swimming? These common experiences show that sound travels through steel and water; in fact, many other liquids, solids, and gases carry sound as well as or better than air. Sound travels about 1100 feet per second in air at a temperature of 32 degrees F. For every added degree of temperature its speed is increased two feet a second. To get the sound produced by a vibrating object from one place to another then, it is necessary only to have some solid, liquid, or gas in contact with the sounding body. A simple experiment may be done to prove this. If an alarm clock be set on a piece of felt or heavy cloth and placed under the bell jar on an air pump, its bell can be heard. If now the air be pumped out of the jar

while the bell is ringing, the sound will be found to grow fainter and fainter as more air is removed until it can hardly be heard. When air is again let into the bell jar the ringing becomes louder. If you have the materials you will find this experiment interesting. Figure 33 will show you how to set up the apparatus.

When sound is reflected from a surface such as a cliff, a building, or a wall, we hear an echo. Echoes may be disturbing in large auditoriums unless the shape of the walls and ceiling is so planned that the echoes which are produced will not be annoying.

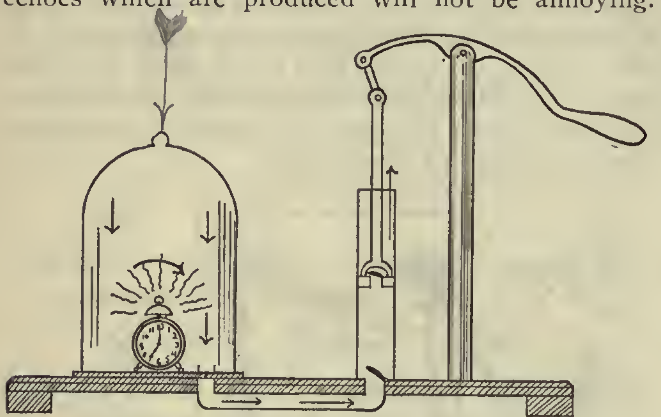


FIG. 33

Oftentimes echoes may be prevented by hanging curtains over the walls that reflect the sound.

Some sounds are pleasing to the ear while others are harsh and displeasing. If a sounding body is sending out a regular vibration such as the one shown at *a* in Figure 34, the human ear recognizes it as a musical tone. But if the vibration is irregular as shown at *b*, we hear what we commonly think of as noise. The only difference between musical tones and noises is in the evenness of the vibration—an even vibration, pleasing tones; an uneven vibration, noise.

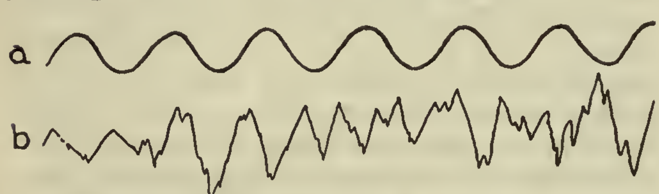


FIG. 34

Sound waves are used to make flying safer. Mail planes and other commercial planes must frequently fly in foggy and stormy weather. A device known as the sonic altimeter has recently been added to the equipment of airplanes to make such flying less hazardous. A sound wave is started by a shrill whistle on the plane and is directed toward the earth. The time taken for the sound wave to reach the earth and to be reflected to the plane is registered by the sonic altimeter. The pilot knows the velocity of sound in air at any given temperature; hence, if he knows the time taken by the sound he can quickly determine his altitude.

Sound waves are used to determine the depth of the ocean. In much the same manner as the aviator may tell his altitude by use of sound, ocean depths may be measured. Sound waves are sent from the surface of the water toward the bottom of the ocean where they are reflected as an echo from a hill or building. The time required for the sound to reach the bottom and be reflected to the surface is noted. The velocity of sound in water is known and thus the depth of the ocean at that point may be easily found.

What is the nature of musical tones? These make possible the great variety of music which can be produced by instruments.

In the first place it is possible for a musical tone to be played loudly or softly, thus permitting the production of many effects with an instrument. Again, musical tones differ in their highness or lowness, or as the musician says, their "pitch." Some tones are very high and others are very low. Knowing that musical tones are produced by vibrating bodies, it is not difficult to see why they vary in pitch. When a body is making only a few vibrations per second it produces a low tone or one that has a low pitch, while one that is making many vibrations each second produces a high note or one that has a high pitch. Middle C on the piano has 259 vibrations per second while the next C above has 517. These tones are eight notes or one octave apart and are tuned to the international pitch.

The octave of any tone makes twice as many vibrations per second as it does. Thus middle C of a tuning fork, 256; C above, 512. Figure 35 shows the scale of eight tones beginning with middle C on the piano and the number of vibrations given by each one.

The human ear can recognize sounds which vary

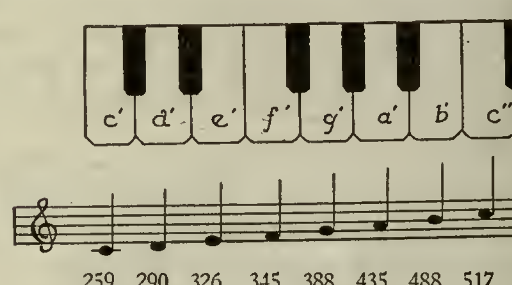


FIG. 35

in pitch from about 16 vibrations per second to 20,000 vibrations per second. Not all ears, however, are the same in this respect, some being more able to recognize high tones while others can better recognize the low tones.

A third important thing about musical tones is that even though a piano and violin are playing a tone of

the same pitch, there is something about each that makes it different from the other. We can always tell a cornet from a trombone by the sound of the tones which they give out. The musician would say that the piano tone has a different *quality* from the violin tone. Difference in quality is due to blending of the overtones with the fundamental tone.

Sounds of great intensity may produce chemical changes. It has been discovered that several chemical substances may be broken down or otherwise changed chemically if they are subjected to sound waves of great intensity and usually of very high pitch. One of the most spectacular effects reported by the investigators was the apparent soft-boiling of an egg by these so-called super-sonic sound waves without the raising of the temperature.

How is the human ear constructed for hearing? It is one of the most sensitive and delicate organs of the human body, having for its purpose the changing of sound waves into nerve currents which are carried to the brain. To show the delicacy of this organ—as I write I hear the ticking of a clock, the sounds of the motor and the horn of an automobile, the scratch of my pen on the paper, and the shrill note of a song bird all at the same instant, and yet my ear takes each air vibration, separates it from the others, and sends the impulses to the brain.

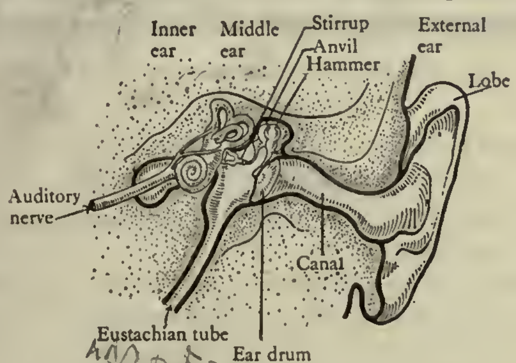


FIG. 36. THE HUMAN EAR

As the diagram (Fig. 36) shows, the human ear is made up of three parts, the outer ear, the middle ear, and the inner ear. Sound waves are gathered by the outer ear and directed into the outer canal, where they strike against the eardrum, setting it in vibration. The middle ear is a cavity in which are three bones known as hammer, anvil, and stirrup because they resemble these devices in shape. The hammer rests lightly against the eardrum and the anvil. The anvil in turn rests against the stirrup, which presses against the membrane of the inner ear. The inner ear contains a liquid which is enclosed in a case of bone. The nerves from the brain end here in the inner ear.

As the eardrum is set in vibration the bone bridge of hammer, anvil, and stirrup takes up the impulse and carries it to the membrane of the inner ear, which also vibrates, setting the liquid in motion. From nerve endings that are highly sensitive to the vibrating liquid, a nerve current is sent along the nerves to the brain.

Also located in the inner ear are the semicircular canals which are shown in the diagram (Fig. 36). These have to do with our sense of balance.

Since the ear is such an important organ and since it is so delicate and sensitive, we should give it great care. Deafness may result from mistreatment. Wax which is found in the ear should never be removed with a sharp instrument, as there is danger of puncturing the ear drum. Take care never to blow the nose too hard or suddenly, for it is often this that forces some infection into the ear. Never slap anyone over the ear. When in swimming, plug the ears with cotton. In case of severe earache it is always best to call the doctor. If these few simple rules are followed you are not likely to have serious ear trouble.

How may different tones be produced on musical instruments? The instruments of an orchestra illustrate clearly the different ways in which music may be produced. The drums produce their tones when a tight membrane is struck a sharp blow with a padded stick. The violins, violas, cellos, and bass viols send out their tones when strings are set in vibration by bowing. The horns such as the cornet, trombone, and French horn contain air columns which are set in motion by the vibration of the player's lip as air is forced past it into the horn. The clarinet, oboe, and saxophone contain air columns which are set in vibration by reeds held in the lips of the player. The organ is a group of air columns which are set in vibration by forcing air past an opening in the pipe.

The pitch of the tones sent out by stringed instruments is changed by changing the length of the string. When a violin player places his finger at a certain point the string will produce a note of given pitch. If he shortens the string the pitch will be raised, while a longer string will produce a lower tone. Observe the strings in a piano. The lowest note produced by striking the last key comes from a string which is long and very heavy. This makes about 32 vibrations per second. The highest note comes from a short, tightly stretched string and gives a tone of about 4,000 vibrations per second.

The human voice is produced by two cords or strands which are stretched over the vocal box in the larynx. As air from the lungs moves past them they are set in vibration, giving out tones that are shaped and moulded by the tongue, cheeks, and lips. The pitch of the tones of the vocal cords is changed by muscles that make them tighter or less tight.

Instruments which depend for their tones upon vi-

brating air columns change their pitch by changing the length of the air column. This is shown clearly in the tin fife or flute. The holes which are covered with the fingers make it possible to change at will the length of the column of air that the instrument encloses. A long air column produces a tone of low pitch while the short ones produce tones of higher pitch.

How does the phonograph reproduce sound? The phonograph is an interesting musical device that has found its way into many homes over the world. It applies many of the principles which have been studied in this topic. A phonograph record is made by recording sound vibrations in a disk of wax by cutting either into the sides of a spiral groove or into its bottom. The sound waves are picked up and made to vibrate a cutting needle which cuts little pieces from the side or bottom of the groove, thereby recording the series of vibrations. If a record is looked at with a magnifying glass these cuts may be seen. The diagram (Fig. 37) shows how they appear.

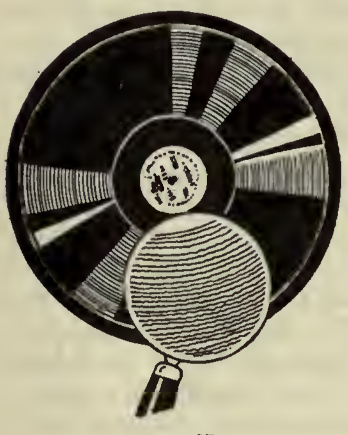


FIG. 37

In the reproduction of the sound by the phonograph the process is reversed. The disk is turned and a needle which follows the groove is caused to vibrate by the little indentations that were cut into the sides or bottom. The needle then causes a disk of rubber to vibrate; in turn the air column of the horn is set in vibration and we hear the original sounds which were recorded on the record. The diagram (Fig. 38) shows the two types of reproducing mechanisms in use. The mechanism represented at *a* is used when the cuts are made in the side of the groove and that at *b* is used when they cut into the bottom.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, pp. 419-430

Clement, Collister, and Thurston, *Our Surroundings*, pp. 170-179

Hunter and Whitman, *Science in Our World of Progress*, pp. 300-305; *Science in Our Social Life*, pp. 300-305

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Watkins and Bedell, *General Science for Today*, pp. 414-419

Webb and Beauchamp, *Science by Observation and Experiment*, pp. 633-645

Wood and Carpenter, *Our Environment: How We Use and Control It*, pp. 122-136

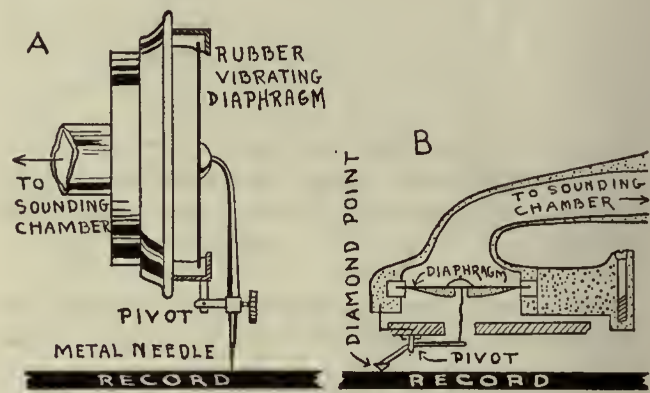


FIG. 38. PHONOGRAPH REPRODUCING MECHANISMS

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. What sound is and how it is transmitted through various substances.
2. How the human ear is constructed and how the various parts working together produce the sensation of sound.
3. Something of how the ear should be cared for.
4. How musical instruments which use strings are constructed and how they produce tones of varying pitch.
5. The construction and operation of some musical instruments which use vibrating air columns.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Sound is produced whenever anything ____.
2. Name the three best conductors of sound.
3. Sound travels (more, less) ____ rapidly on a warm day than on a cold day .
4. The outer ear directs sound waves into the ____, where they strike against the ____ and cause it to vibrate. The middle ear contains three bones called ____, ____, and ____. These bones convey the vibration to the inner ear, which contains a ____. Nerves carry the sensation from the inner ear to the ____.
5. A noise is produced by ____ vibrations, and a musical tone is produced by ____ vibrations.
6. In making a phonograph record, what do the sound waves cause to vibrate? From what are pieces cut?
7. When a phonograph is played, what is caused to vibrate by the grooved disk? What is the direct cause of the vibration of air in the horn?
8. The slide trombone produces tones of different ____

by changing the ____ of its vibrating ____ columns.

9. A short string has a (lower, higher) ____ pitch than a long string of the same material and diameter. A long air column has a (lower, higher) ____ pitch than a short column.

10. A phonograph record when played fast appears to have (higher, lower) ____ pitch.

11. Pitch depends upon the number of ____ per second.

12. Sound travels in air (1100, 2000) ____ feet per second at thirty-two degrees Fahrenheit or zero degrees centigrade.

13. Often an echo reflected from a building or hill blends in with the sound of the vibrating object and may not be distinguished from it. Infer the probable cause of this.

14. On the basis of the facts learned in this topic, infer why it would be impossible as far as scientific knowledge now goes to receive sound signals from other planets in our solar system such as Venus or Mars.

15. When a violinist tunes his violin he turns small axles to which the strings are attached. Infer how this changes the pitch of the strings.

16. Musicians in an orchestra always warm up their wind instruments before playing. Can you infer a reason for this?

TOPIC 5. AIR AND LIVING THINGS

SUGGESTED PROBLEMS AND QUESTIONS

1. **What are the differences between physical and chemical changes?**
2. **Of what is air composed?**
3. **What is the nature of burning?**
4. **Why do plants and animals breathe?**
5. **What is the importance of fresh air and how is it best obtained in our buildings?**

SUGGESTIONS AND HELPS FOR STUDY

1. Follow the same method as outlined in Topics 1 and 2.

2. Try to find answers to the following questions either by reference study or by experiment.

a. Problem 1

What is a physical change?

What is a chemical change?

How do substances appear after each has taken place?

b. Problem 2

How may air be taken apart? (See Experiment 13.)

How may the parts be tested? (See Experiment 13.)

c. Problem 3

What happens when a can rusts?

Will anything burn without air? (See Experiment 16.)

How does the weight of a substance compare before and after burning?

Is air the same before and after a substance has been burned in it?

d. Problem 4

What do plants and animals take out of the air?

What do plants and animals give back to the air?

What use is made of the substance taken in?

What is oxidation?

Compare in detail a burning candle with oxidation in a plant or animal.

e. Problem 5

How does exhaled air compare in weight, volume for volume, with fresh air?

How should windows be regulated to care for this difference?

What precautions are necessary in ventilating a room?

3. You may find the following new words and phrases in this study:

compound—a new substance formed when two or more simple substances combine chemically.

element—a simple substance which cannot be broken down into simpler substances; for example, sulphur, tin, zinc, aluminum, hydrogen, nitrogen.

exhale—to breathe out.

hæmoglobin—the substance which gives the color to red corpuscles in the blood.

inhale—to breathe in.

kindling temperature—the temperature at which a substance takes fire and burns.

mixture—a combination of two or more substances in such a way that their nature is unchanged; for example, a mixture of lead shot and sand.

molecule—the smallest particle of a substance which still retains the properties of that substance; for example, the smallest particle of wood, leather, glass.

oxidation—chemically combining some substance with oxygen as the burning of coal or the rusting of a can.

oxide—a chemical compound made up of oxygen and some other substance.

respiration—the exchange of gases between living things and the air.

ventilation—providing a free circulation of fresh air in a room or building.

EXPERIMENTS OR DEMONSTRATIONS THAT WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 13. How may air be separated into its parts?

Moisten the inside of a test tube. Pour in iron filings and then pour out all that do not cling to the inside. Invert the test tube in a dish of water and leave for 24 hours. Test the gas remaining in the tube with a lighted splint.

In your notebook[1] record the notes of this experiment and complete the statements given below.

The water ____ in the tube about ____ of the way toward

[1] See accompanying workbook, p. 9.

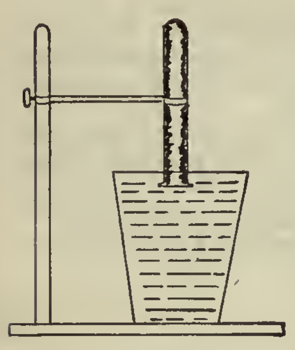


FIG. 39

the top. The iron appeared to have changed color to a ____. This substance is commonly called iron ____. The gas left in the tube ____ to support burning. If the brown iron rust is made of iron and oxygen it has secured the ____ from the air. If it has removed all of this substance about ____ of the air is oxygen and about ____ is other gases.

Experiment 14. How may oxygen be prepared?

Set up the apparatus as shown in Figure 40. Place in the test tube a mixture of about four parts potassium chlorate to one of manganese dioxide. Replace the stopper. Heat the tube. Collect three bottles of the gas in bottles which have been filled with water and inverted in the pan. The bottles may be inverted by placing a glass plate over the mouth of the bottle. Place a smouldering splint in one bottle of the gas. Heat some fine iron wire in a

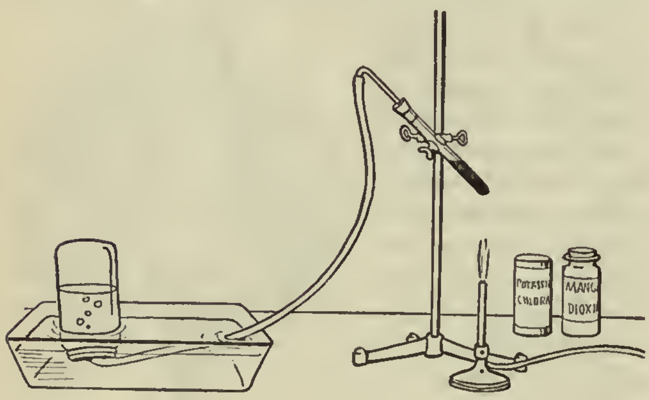


FIG. 40

flame and dip it into some sulphur. Light the sulphur and plunge it into another bottle of the gas. Burn some other substance in the other bottle of oxygen.

In your notebook[1] record the notes of this experiment and complete the statements given below.

Things burn ____ in oxygen than in air. Oxygen may be prepared by ____ a mixture of ____ and ____. Oxygen has no odor, ____, or ____.

Experiment 15. How may carbon dioxide be prepared?

Insert a one-hole rubber stopper into the mouth of a pint milk bottle. Through the hole in the stopper place a six-inch length of glass tubing bent at an angle. Attach a delivery tube to the generator. Place several lumps of marble in the generator, cover them with water, and add some concentrated hydrochloric acid. Collect the gas by placing the delivery tube in a bottle. Allow some of the gas to bubble through the clear limewater as shown in Figure 41. *This is a test for the presence of carbon dioxide.* Plunge a burning splint into a bottle of carbon dioxide. Observe the results in the generator and the tests.

[1] See accompanying workbook, p. 9.

In your notebook[2] record the notes of this experiment and complete the statements given below.

FIG. 41

When the ____ acid was poured on the ____ a ____ gas was given off which was heavier than air as shown by the way ____. When the gas bubbled through limewater, the limewater changed to a ____ color. A burning splint placed in a bottle of carbon dioxide ____, showing that carbon dioxide will not ____ burning.

Experiment 16. What is given out by a burning substance?

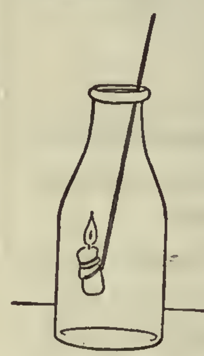


FIG. 42

a. Wind a one-foot length of wire several times around a piece of candle. Light the candle and lower it into a quart milk bottle or jar. Carefully observe what happens. Pour some clear limewater into the jar, close the mouth with your hand or a cork, and shake thoroughly.

b. Bring the burning candle near a cool blackboard so that the flame touches the slate, and observe what happens.

In your notebook[3] record the notes of this experiment and complete the statements given below.

When clear limewater was placed in the jar in which the candle had burned, it turned ____, showing that ____ was given off as a product of the burning. The ____ came from the ____ while the ____ came from the air.

When the candle came in contact with the cold blackboard a little spot of ____ was formed, showing that another product of burning is ____.

Experiment 17. Does slow burning take place in the body?

Have several members of the class blow their breath through the clear limewater and observe what happens.

In your notebook[4] record the notes of this experiment and complete the statements given below.

When the breath was blown through clear limewater it ____, showing the presence of ____. This is evidence that a ____ which results in the formation of ____ has taken place in the ____. The ____ came from the ____ we eat while the oxygen came from the ____ which we ____.

Experiment 18. What are the important things in securing good ventilation?

Make an airtight ventilation box as illustrated in the diagram (Fig. 43). A box about 12 x 12 x 10 inches is of a good size. The front should be made with a sliding glass door. Bore four holes in each end, two at the top and two

[2] See accompanying workbook, p. 10.
[3] See accompanying workbook, p. 10.
[4] See accompanying workbook, p. 11.

at the bottom, about one inch in diameter. These should be closed with rubber stoppers. Any air leaks in the box may be closed with putty. Place four candles in the box, close the door, and stopper all the end openings, which may now be thought of as closed windows. By varying the openings, find out the best conditions for ventilation.

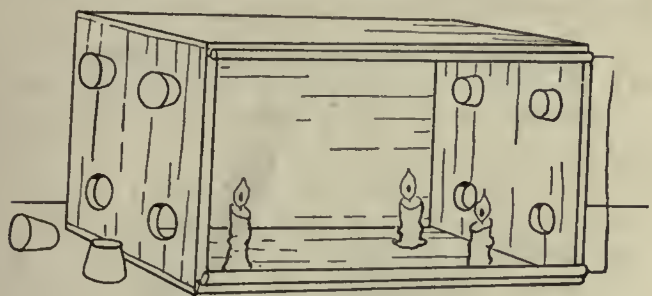


FIG. 43

In your notebook[1] record the notes of this experiment and complete the statement given below.

I find the best conditions for ventilation to be ____ as indicated by this experiment.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

Will things burn without air? Devise a method to test out this question.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What are the differences between physical and chemical changes? When two or more simple substances are combined in such a way that each has lost the things, such as color, odor, and taste, by which it was recognized, and a new substance is formed, they are said to have been chemically united. The change which has taken place is called a *chemical change*. The rusting of a can, the cooking of meat, the burning of wood, coal, or paper, the baking of a cake all are examples of this type of change. If simple substances are put together in such a way that they may still be taken apart and recognized by their color, odor, or taste, they are said to have been mixed, and the change is called a *physical change*. Some examples are wood changed to sawdust, water changed to ice or steam, iron changed to iron filings. Can you think of others?

Of what is air composed? The blanket of air which surrounds our earth is a mixture of several gases, all of which are colorless and odorless and have no taste. These conditions explain why we are so little aware of the presence of an atmosphere. The table below shows the composition of the air and gives the amounts of the gases present in the greatest quantity.

Nitrogen	78.02%
Oxygen	21.00%
Argon	.93%
Carbon dioxide	.04%
Water vapor	Variable
Helium, Neon, Xenon, Krypton	Rare gases present only in small traces

[1] See accompanying workbook, p. 11.

Nitrogen, which makes up most of the air, is one of the necessary substances for all living things, but strange to say, they do not obtain it directly from the atmosphere. It must first be put into the soil in a form which can dissolve and then be absorbed into plants whch are later eaten by animals and man. Great amounts of money are spent each year for fertilizers that contain nitrogen. During the recent war our government spent several millions of dollars to build a chemical plant at Muscle Shoals, Alabama, which could take the nitrogen from the air and combine it with other substances to make high explosives in the time of war or fertilizers in peace times.

Oxygen, which makes up about one fifth of the air by volume, is necessary for all life. Without it this earth would be a barren place, for no animal could live and no fires could burn. Oxygen is very active, that is, it unites with a great many other things to form chemical compounds. Many common substances in our everyday lives contain oxygen chemically united with one or more other elements. Iron rust is made up of iron and oxygen; water is hydrogen and oxygen; starch and sugar are made of carbon, hydrogen, and oxygen; sand is made of a substance called silicon and oxygen—in fact, oxygen is so active that it is seldom found free except in the air, where the other gases are so inactive that they will not unite with it except under special conditions.

Argon is a gas that resembles nitrogen in many ways. It does not combine easily with other substances, and because of this it is sometimes used in gas-filled electric lamps to keep the tungsten filament from evaporating when it gets very hot.

Carbon dioxide is a gas that is given off by all living things. It is also formed whenever anything containing carbon burns. Only a small percentage of air is carbon dioxide. In 10,000 gallons of air you would find only three or four gallons of carbon dioxide. This gas is important because it is again taken out of the air by green plants as they build up food material in their leaves.

There is always some water vapor present in the air, but it varies greatly from day to day. The moisture in the air, which is an important factor in weather, climate, and health, will be studied in detail in the next unit, "The Weather and Climate About Us."

The other gases found in the atmosphere, helium, neon, krypton, and xenon, are called rare because only traces of them are found. Two of these gases have

come to be important in the past few years. Helium, because it is very light and will not explode, is used for filling dirigible balloons. It is, however, obtained from natural gas wells in Texas rather than from the atmosphere. Neon is now used a great deal in the making of electric signs and in some of the tubes used in television.

FIG. 44. USES OF RARE GASES OF THE ATMOSPHERE

What is the nature of burning? It is a familiar experience that the fuel in a stove, a furnace, or a bonfire will burn best when there is a good draft of air flowing to the fire. Only the oxygen of the air is used in burning, the other gases passing up the chimney unused.

Oxygen is always needed when anything burns, as burning is simply the substance uniting chemically with oxygen to form a new chemical compound. Let us examine some common substances which burn and discover what really happens. Coal is almost pure carbon, and when it combines with oxygen it does so with such speed that quantities of light and heat are given out and a new substance, carbon dioxide, is formed. The chemist has an interesting way of showing this combination in much the same manner as that in which you would write an equation in mathematics. He would write

carbon + oxygen = carbon dioxide

Many of you have smelled the odor of burning sulphur which is sometimes used as a disinfectant. When it burns it also unites with oxygen thus—

sulphur + oxygen = sulphur dioxide

It is the sulphur dioxide that has the irritating odor.

When iron rusts it unites with oxygen in the same way as the carbon and sulphur do.

iron + oxygen = iron oxide

The new chemical substance formed when things unite with oxygen is called an oxide.

There is a difference in the burnings explained above. In the case of carbon and sulphur, it is so rapid that heat and light are also given out. The burning of iron takes place so slowly that the heat produced is not noticed, and the burning is said to be slow, while with the carbon and sulphur it is spoken of as rapid. Very rapid burning takes place whenever anything explodes, for an explosion is simply the very rapid uniting of some substance with oxygen. The great English dirigible *R-101*, which exploded in 1931, was filled with hydrogen, a very light and highly explosive gas. When hydrogen explodes it unites very rapidly with oxygen, forming hydrogen oxide or water.

hydrogen + oxygen = water

Why do plants and animals breathe? To carry on the different activities which living things are called upon to do, such as moving, growing, breathing, and digesting food, it is necessary that they have energy. This is obtained from the food which they eat, but it can be obtained only when oxygen is present to unite with the foods, or slowly burn them, and set free the energy that they contain. This is exactly the same thing that happened to the coal or carbon when it was burned. As it united with the oxygen of the air it gave out the energy, and a new substance, carbon dioxide, was formed.

Much of the food that we eat for energy purposes, such as sugar and starch, contains carbon. This food is digested and carried by the blood stream to the different parts of the body. Air is taken into the lungs and the oxygen is removed by the blood, which takes it to the parts of the body in which energy is being used, such as the brain or a leg or arm muscle. Here the slow burning takes place, the energy is set free, and carbon dioxide is carried back by the blood to the lungs, where it is passed off as we exhale or breathe out. The simple experiment of blowing the breath through clear limewater demonstrates this fact.

All living things secure the oxygen which they must have to carry on life and also give out carbon

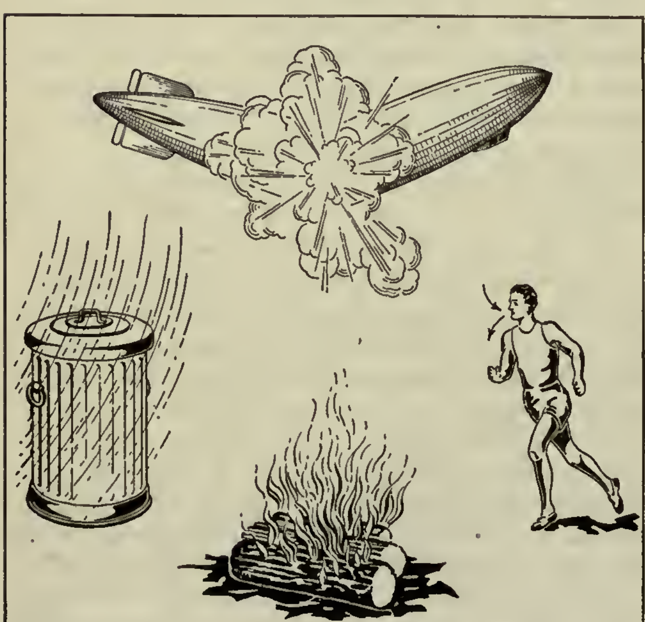


FIG. 45. SUBSTANCES BURN AT DIFFERENT RATES

dioxide as a result of the slow burning which has taken place. Fish have gills which enable them to secure their oxygen from the air that is dissolved in water. Trees and other plants obtain oxygen through leaves and stems which have openings into the interior of the plants.

FIG. 46. A BALANCED AQUARIUM

Oxygen for things which live in water is also obtained from green plants that live in the water. As these plants make food for themselves, oxygen is a waste product and is breathed out through the same openings which take in air dissolved in water. This is the reason that green plants are important in an aquarium.

What is the importance of fresh air and how is it best obtained in our buildings? Air may be easily made unfit for breathing by the presence of dust particles, by tiny plants called bacteria, some of which cause disease, and by gases which are given out from the chimneys of some manufacturing plants and from automobile engines running in closed buildings.

While the removal of some of these impurities from the air that we breathe is beyond our control, one may do a great deal toward freeing his city from smoke; this is one of the greatest problems of some of our modern cities. In some places laws preventing any industry, apartment house, or other large building from throwing out dense smoke are carefully enforced. If your city has a smoke law, secure information about it and do what you can to coöperate in its enforcement.

The coming of the automobile has brought a problem of impure air which seems to be one of the most important of the present and future. You have already learned that when anything containing carbon burns, one of the products formed is carbon dioxide. This is true, however, only when the burning takes place where there is a plentiful supply of oxygen. Carbon dioxide is harmless and may be breathed without fear. If, on the other hand, a substance containing carbon is burned where there is only a limited supply of oxygen, another oxide called carbon monoxide is formed.

carbon + oxygen (limited) = carbon monoxide

Carbon monoxide is very poisonous even when breathed in small quantities. In the cylinder of an automobile where the gasoline, which contains carbon, is exploded, the air supply is limited and, therefore, some of the gas which is thrown out by the exhaust of the car is carbon monoxide. When this is allowed to accumulate as in a closed garage, it soon makes the air unfit to breathe and will overcome and cause the death of any living thing breathing it. Never start or leave an automobile engine running in a closed garage. To do so may cost you your life.

So much of our lives is spent indoors that we should be very careful to insure in our working and sleeping places an ample supply of fresh air free from draft. Estimates vary regarding the amount of pure air needed by each person, but there should be provided at least 1600 cubic feet per hour per person. Everyone becomes uncomfortable in a closed room, not so much from a lack of oxygen as from the increase in the water vapor present in the air. Provision should be made so to ventilate rooms that the breathed air can be readily removed while fresh pure air is constantly supplied.

Air which has been breathed is warmer and lighter, volume for volume, than fresh air, and so will be pushed to the top of the room by the cool, heavier fresh air. If a window is open at both the top and bottom, cool fresh air can come in at the bottom and push the lighter warm air out at the top. If possible, a window in one part of the room should be open at the bottom and one in another part of the room at the top, thus providing for a circulating of the fresh air.

Since there is danger from draft, it is wise to place

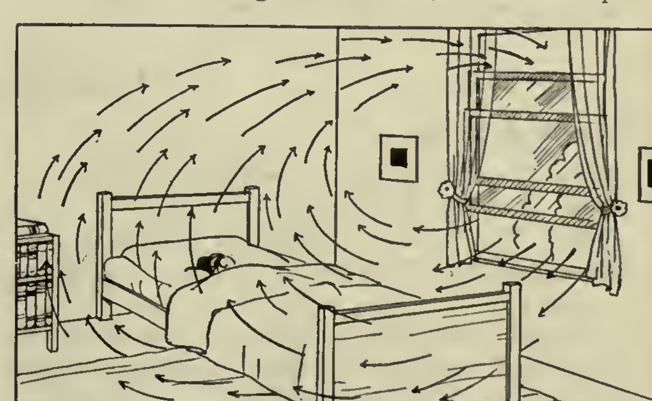


FIG. 47. PROPER VENTILATION

at the lower opening of the window a board or screen which slants inward. This will give the incoming air an upward motion and will prevent it from blowing on a person near the window.

Air conditioning is important in modern homes and public buildings. During the past few years many

homes and public buildings such as theaters have been equipped with machinery to condition the air which is used in them. Air conditioning means the controlling of the conditions of air which make for comfort and good health.

In the past almost the only attempt to condition the air of our homes was to heat it in the winter time. In the newer process the air is not only heated in winter and cooled in summer but is washed free of dust and is given the proper amount of moisture content for good health. In a later unit of this book you will learn how this is accomplished as you study the devices used for heating homes.

REFERENCES FOR FURTHER STUDY

Caldwell and Curtis, *Science for Today,* pp. 27-38

Clement, Collister, and Thurston, *Our Surroundings,* pp. 34-35

Hunter and Whitman, *My Own Science Problems,* pp. 67-72

Lake, Harley, and Welton, *Exploring the World of Science,* pp. 38-47

Pieper and Beauchamp, *Everyday Problems in Science,* pp. 225-233

Powers, Neuner, and Bruner, *The World around Us,* Chaps. 11-14; *Man's Control of His Environment,* pp. 601-611

Van Buskirk and Smith, *The Science of Everyday Life,* pp. 42-46

Watkins and Bedell, *General Science for Today,* pp. 4-5 and 275-278

Webb and Beauchamp, *Science by Observation and Experiment,* pp. 223-227

Wood and Carpenter, *Our Environment: How We Use and Control It,* pp. 141-176

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Something of the make-up of the air and the chemical nature of its important parts.
2. The meaning of the terms *burning* and *oxidation.*
3. The difference between physical and chemical changes.
4. The importance of air to the life processes of plants and animals.
5. The importance of good ventilation to health, and the best methods of securing it.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Of what three elements is air chiefly composed?
2. A test for the presence of oxygen is to thrust a ____ into a jar believed to contain oxygen.
3. When a can rusts the (iron, tin) ____ of which it is made has united with the (air, oxygen) ____ of the air to form (an oxide, water) ____.
4. The rusting of a can is ____ oxidation, while the burning of a candle is ____ oxidation.
5. Oxygen may be prepared by heating a mixture of ____ and ____.
6. The ____ of clear ____ is a test for carbon dioxide.
7. Carbon dioxide may be prepared in the laboratory by the action of ____ on ____.
8. What changes take place when a substance burns? Explain each change.
9. Smoke is ____ gases and fine ____ material carried from the fuel.
10. What happens to the nitrogen in the air when a substance burns?
11. Why does the air not become filled with carbon dioxide which is given out by all living things and most things that burn?
12. What are the important things to remember in ventilating a room?
13. By means of a drawing show your sleeping room and how you secure your ventilation. Is your room properly ventilated?

SUPPLEMENTARY MATERIALS

Reading suggestions

Clarke, *The Boys' Book of Chemistry* (Dutton)

Collins, *Wonders of Chemistry* (Crowell)

Collins, *Boy's Book of Experiments* (Crowell)

Fournier D'Albe, *Wonders of Physical Science* (Macmillan)

Bond, *On the Battle Front of Engineering* (Century)

Cochrane, *Wonders of Modern Mechanism* (Lippincott)

Moffett, *Careers of Danger and Daring* (Century)

Corbin, *The Romance of Submarine Engineering* (Lippincott)

Bragg, *The World of Sound* (Dutton)

Bond, *With the Men Who Do Things* (Scientific American)

Davis, *The Advance of Science* (Doubleday)

Fisk, *Exploring the Upper Atmosphere* (Oxford)

Talman, *The Realm of the Air* (Goodheart)

Riesbeck, *Air Conditioning* (Bobbs)

Reports which may be prepared

1. Exploration of the upper atmosphere
2. Historic altitude flights of airplanes and balloons
3. The history of pumps
4. The uses of compressed air
5. An hour in a caisson
6. Building a tunnel under a river
7. The discovery of the air brake
8. The building of a subway
9. Working under water
10. The musical instruments of primitive people
11. Sounds of the world about us
12. Sound in music
13. The first balloon ascension

14. Early gliders
15. The beginnings of the airship
16. The submarine
17. Deep sea divers
18. The air conditioning of homes and theaters

Great scientists you should know about

1. Otto von Guericke
2. Blaise Pascal
3. Evangelista Torricelli
4. Galileo Galilei
5. George Westinghouse
6. Karl W. Scheele
7. Joseph Priestley
8. Antoine Lavoisier
9. Wilhelm von Helmholtz
10. John Tyndall

Investigations and things to do

1. Make a mercury barometer.
2. Make an aneroid barometer.
3. Build a wind vane.
4. Make a lung capacity bottle and measure the lung capacity of the members of your class.
5. Make a self-starting siphon.
6. Make a windmill.
7. Make a cigar box violin.
8. Experiment with vibrating strings.
9. Experiment with vibrating air columns.
10. Study the effects of varying amounts of air on plants.
11. Make a working model of the lungs.
12. Make a scrapbook of clippings dealing with one of the recent stratosphere flights.

UNIT II. THE WEATHER AND CLIMATE ABOUT US

In many ways we are affected by the weather. It determines the type of clothing we wear, influences our play, and is one of our most common topics of conversation. Our food and water supplies are directly affected by the weather, which also plays an important part in our health.

The world's business, which indirectly affects each of us, is dependent to a great degree upon weather. Many of our crops such as wheat, corn, and cotton depend upon favorable weather; with unfavorable weather conditions the people dependent upon these crops are deprived of their livelihood. Prediction of approaching cold waves and storms helps the farmer and the fruit grower and shipper. Not long ago the prediction of an approaching hurricane by the United States Weather Bureau made it possible for cargoes valued at more than $50,000,000 to reach protecting ports safely. Many other forms of business such as the selling of coal, ice, and ice cream are directly dependent upon weather and climate for their success or failure. Holders of food concessions in large public parks frequently consult weather reports in order to determine whether the majority of picnickers on a certain day will purchase "hot dogs" or ice cream.

Weather prediction has reached a high degree of certainty. Knowledge gained through many years of careful observation and results obtained in exploring the upper atmosphere have made this possible. Expeditions to Greenland and other parts of the North, together with Admiral Byrd's Antarctic expedition, have provided scientists with new material which may aid in solving many puzzling problems of storm prediction.

Weather prediction is so important in industry, business, navigation, and our immediate everyday lives that the government maintains a large organization to care for it. This organization has its headquarters at Washington, D.C., and is known as the United States Weather Bureau. The weather forecasts are based upon observations of local weather from more than three hundred stations scattered over the country. Observations are also received from Alaska, Canada, Mexico, and ships at sea. On the basis of the observations made, daily weather maps and bulletins are mailed from a hundred or more distributing points. These maps reach nearly 100,000 addresses daily, which represent only a small fraction of all the people receiving benefit from this remarkable service.

For centuries, in every land, the weather has been such an absorbing topic that many quaint weather rimes and sayings have grown up. Some of these are scientifically accurate, while many have not the slightest element of truth in them. These sayings, commonly called weather lore, are fascinating, and it is hoped that you will find time during this study to acquaint yourself with many of them and to determine their accuracy from a scientific viewpoint.

In this introduction the many ways in which weather affects you have been pointed out. In the study of the unit you will learn more interesting things about weather and the laws and principles of science which control it.

How many of these questions about the weather can you answer? In your notebook write as many of the answers as you can.

1. How accurate are the predictions made by the U. S. Weather Bureau? Cut from the paper each day for a period of four days the local prediction of the weather. Paste this neatly in your notebook and date it. Carefully observe the weather for each day and make a note as to its accuracy.
2. In what ways has the climate of your locality determined the mode of living there?
3. List some of the factors which you regard as important in predicting the weather.
4. Show as many ways as you can in which the climates of North America have determined the modes of living of the various tribes of American Indians.
5. Make a drawing representing the earth as a circle about two inches in diameter. On this place the various climate belts of the earth and name the lines which divide them.
6. What causes the climate of California to be so pleasant when other parts of the country in the same latitude may be having extremely cold weather?
7. How do you acount for the fact that tornadoes seem to be especially numerous in the Middle West?
8. What causes a thunderstorm?
9. List as many ways as you can in which a person living in New York lives differently from one in Lima, Peru, because of weather or climate.
10. In what ways is weather prediction of importance?
11. What are some of the recent developments in weather forecasting?
12. Show how weather forecasting is becoming increasingly important to aviation.
13. Do you think that the recent stratosphere flights might add anything to our knowledge of weather and aid the accurate prediction of the weather? Explain your answer.
14. Why do you think Admiral Byrd took trained weather forecasters with him on both of his expeditions into the Antarctic? Of what value could the knowledge gained by these scientists be for weather forecasting in general?

TOPIC 1. HOW MOISTURE GETS INTO THE AIR

SUGGESTED PROBLEMS AND QUESTIONS

1. **Where does moisture in the air come from?**
2. **What is evaporation and what are the factors which affect it?**
3. **What is the importance of relative humidity and how is it measured?**
4. **How does the electric refrigerator work?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully review the study plan suggested on page 1. The answers to the following questions will aid in the solution of problem 2.

a. What examples of evaporation have you noticed?

b. What happens when evaporation takes place?

c. What sort of evaporation is boiling?

2. Your solution of problem 2 will be aided by learning the factors which affect evaporation and then experimenting with them. Several experiments are suggested below.

3. In solving problems 3 and 4, try to find answers to the following questions either in your reference study or by carrying on experiments.

a. When evaporation takes place, what is the effect upon the temperature of the surroundings?

b. How does evaporation affect our body temperature?

c. Why does an electric fan make one feel more comfortable on a hot day?

d. How does relative humidity affect our health?

e. How may relative humidity be determined?

4. You may find the following new words and phrases in this study:

dew point—the temperature at which dew begins to form because of the condensation of the moisture in the air.

evaporation—changing from the liquid to the vapor state.

humid—moist, filled with water vapor.

humidity—the moisture in the air.

precipitation—water which comes out of the air in the form of rain, snow, or sleet.

relative humidity—the amount of moisture actually present in the atmosphere at any temperature compared with the amount which could be held without precipitation at the same temperature. It is usually expressed in percentage.

saturated—completely filled.

vaporize—to change from a liquid to a vapor.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 19. What factors affect evaporation?

a. With a cloth or sponge moisten two spots of equal size on a blackboard or a piece of slate. Fan one spot and leave the other undisturbed.

b. Warm a place on a blackboard or a piece of slate by shining an electric heater on it, or by a gas flame. Moisten a spot on this warm place and another of equal size on a colder portion. Leave them for a few moments and observe closely.

c. From wooden strips about two inches by one inch and eighteen inches long, make a square frame. Secure an old towel or piece of cheesecloth and tack over this frame. Wet the cloth thoroughly. Moisten two spots of equal size on the blackboard or a piece of slate. Leave one open to the air and place the frame over the other. Observe them after several minutes.

In your notebook[1] record the notes of this experiment and complete the statements given below.

a. The moisture from the ____ spot evaporated more rapidly. This shows that wind (aids, retards) ____ evaporation.

b. The water on the spot which was warmed ____ ~~the~~ water vapor ____ rapidly than did the one which was not warmed.

c. Water will evaporate more rapidly if the air near it is ____. This was proved when the water evaporated from the (open, covered) ____ spot more rapidly than from the one which was ____.

Experiment 20. Does evaporation cool?

Place a few drops of alcohol on the back of your hand and notice the result. Write your observations and inferences from this experiment in your notebook.[2]

Experiment 21. How may the relative humidity of the air be measured?

Secure two thermometers which read exactly alike. About the bulb of one place a piece of cheesecloth which has been moistened in distilled water. Fan the wet bulb and set the dry-bulb thermometer aside. When the mercury of the wet bulb has gone down as low as it will go, read and record the temperature of each thermometer. Record your results in your notebook.[3] Study carefully the table on page 30 and find the row of figures across the top marked as the "difference between the dry-bulb and wet-bulb reading." Find the difference which your experiment gave. Read down the column of figures under that difference until you come to the one opposite the reading of the dry-bulb in the column at the extreme left. This is the relative humidity for the time of your experiment. For example, if your dry-bulb reading is 71 degrees and the

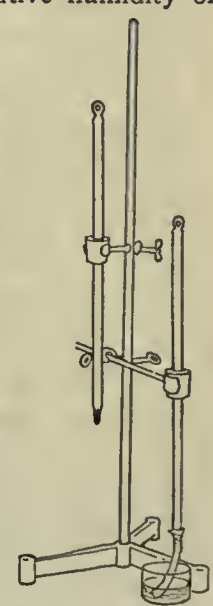


FIG. 48

[1] See accompanying workbook, p. 12.
[2] See accompanying workbook, p. 12.
[3] See accompanying workbook, p. 13.

difference between the wet- and dry-bulb readings is 10 degrees, find 10 in the difference column and read down until you come opposite 71 in the extreme left row. Read 56 per cent as the relative humidity.

Record the notes and results of this experiment in your notebook.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Where does the moisture in the air come from? The blanket of air that surrounds the earth is like a great sponge. Sometimes it contains only a little moisture and can soak up large amounts of water. At other times it is wet and can take up little or none. This vapor comes from many sources. You have all breathed on a cold mirror or window pane and noticed that water vapor is deposited. Many living things, both plant and animal, give moisture to the air. Almost every chimney in the world pours water vapor into the air, because most fuels contain hydrogen, which forms water vapor as it unites with oxygen and burns. By far the greatest amount of moisture, however, is furnished the air from the bodies of water, such as oceans, lakes, and streams, which are spread over the earth.

What is evaporation and what are the factors which affect it? When a liquid turns into a gas or vapor it is said to evaporate, and the process is called evaporation. Water, a colorless liquid, evaporates into steam, an invisible vapor. What we commonly speak of as steam is not steam at all, but condensed water particles. From the great bodies of water over the earth, water gets into the air-sponge by evaporation, which may take place slowly or rapidly. If the air-blanket contains much water vapor, evaporation is slower, while if it is drier the process goes on much more rapidly. Since warm air can hold more water vapor than cold air, when the air is warm evaporation usually goes on more rapidly than when it is cold.

FIG. 49

The energy of the sun controls evaporation of water into the air. Everyone knows that wet clothing will dry most quickly on a warm, dry, windy day. This is true because all of the factors which control evaporation are favorable to moisture's getting into the air. Since warm air can hold more moisture than cold air, and since the wind circulates the air so that

RELATIVE HUMIDITY TABLES—FAHRENHEIT

Temperature readings in degrees Fahrenheit. Relative humidity readings in per cent. Barometric pressure 29.0 in.

Readings of Dry-Bulb Thermometer	Differences in Degrees Fahrenheit Between Wet- and Dry-Bulb Thermometers																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18	14	10	6	2
61	94	89	84	79	74	68	64	59	54	50	45	40	36	32	28	24	20	16	12	8	4
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17	13	9	6
63	95	90	84	79	74	70	65	60	56	51	47	42	38	34	30	26	22	18	14	11	7
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20	16	12	9
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21	17	13	10
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15	11
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23	20	16	13
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17	14
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25	22	19	15
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20	17
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27	24	21	18
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22	19
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29	26	23	20
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34	31	28	25	22
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26	23
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36	33	30	27	24
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28	25
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37	34	31	29	26
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35	32	29	27

a fresh supply is always in contact with the clothes, they will dry rapidly. The sun's rays warm the air and, as you will learn later in this unit, this heat from the sun not only aids evaporation but also is the cause of winds.

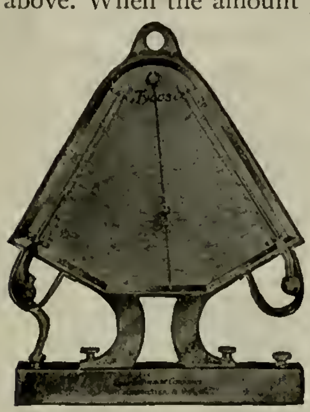
Clothes will not dry on a damp day because the air around the clothes is nearly filled with moisture and unable to take up much more. However, a wind blowing fresh air to them, even on a damp day, will greatly aid the evaporation of the water.

What is the importance of relative humidity and how is it measured? The amount of water vapor in the air varies from day to day. All have experienced those sultry days in midsummer when the clouds hang low and one perspires easily. We commonly speak of such days as "humid." We have also experienced the other extreme of a cold, dry day in winter. On a humid day the air-sponge is nearly full; on a crisp, dry day in winter it contains much less moisture.

Tycos
FIG. 50
HYGROMETER

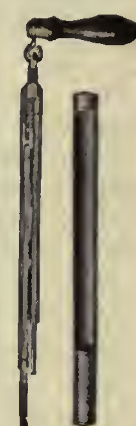
As you have already learned, warm air can hold more water vapor than cold air, and further, at any given temperature it can hold only a certain amount. When this amount has been reached, the air is said to be saturated or filled and can hold no more unless the temperature rises. When the air at any given temperature is completely saturated it is said to be 100 per cent filled. If it contains only half as much as it can hold at that temperature it is 50 per cent filled.

The amount of water vapor actually present at any temperature compared with the amount which the air can hold at that same temperature is called relative humidity. This is expressed in percentage as explained above. When the amount present is half that which the air can hold, the relative humidity is 50 per cent.



Tycos
FIG. 51. HYGRODEIK

The relative humidity is usually measured with one of the devices shown in Figures 50, 51, and 52. These are slight variations of the wet- and dry-bulb method which you used in your experiment. The evaporation from the wick of the wet bulb is controlled by the moisture or dryness of the air about it. The heat needed for this evaporation is taken from the thermometer, which becomes cooler and as a result reads lower. The difference of temperature between the wet and dry bulbs measures the rate of the evaporation. Tables like the one on page 30 have been prepared to give the relative humidity from the readings of the wet- and dry-bulb thermometers. Figure 50 shows a common form of the wet- and dry-bulb hygrometer which is fastened to the wall. The hygrodeik (Fig. 51) is made with tables printed on it so that the relative humidity may be obtained directly. The psychrometer (Fig. 52) is composed of the wet- and dry-bulb thermometers so constructed that they may be rapidly spun around. This gives a more accurate reading than either of the other instruments.



Tycos
FIG. 52
PSYCHROMETER

When the relative humidity is too low in our homes and buildings, the moisture from the skin and from the linings of the nose and throat tends to dry out. This seems to create a condition favorable for germs of various types and may lead to colds and other diseases. When the relative humidity is between 50 and 65 per cent we have the most healthful condition.

Buildings in which the relative humidity is kept between these points are easier to heat because a room which is dry causes the evaporation of body moisture and a consequent cooling. A room at 68° F. and 60 per cent relative humidity is more comfortable than one at 72°F. and 35 per cent relative humidity. When humidity is low, furniture and woodwork dry out and crack.

Several different types of home humidifiers are on the market for homes heated by steam or hot water. Usually these are some type of water pan which is placed on the radiator so that the water in the pan will be warm enough to evaporate rapidly. For hot air heating systems, water pans are placed in the furnace jacket, and as the warm air passes through it may take up some of the water. Large buildings such as theaters, hotels, and hospitals usually have humidifying systems built in with the ventilating system.

How does the electric refrigerator work? One of the experiments taught you that heat aids evaporation. It is a familiar fact that a kettle of water must be placed over a fire to boil. Liquids must have heat to evaporate into gas or vapor, and when they absorb this heat, energy is taken from the surroundings, such as the fire or whatever they are in contact with. If a drop of a liquid which easily evaporates is placed on the hand, the hand will feel cold. When one comes from a bath and stands over a register or near a heater he may feel very cold, because the warm air currents

increase the rate of evaporation from the body. Whenever heat is removed from anything it is cooled, and

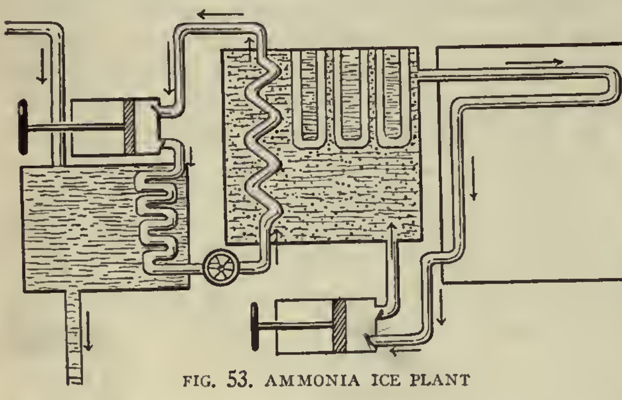


FIG. 53. AMMONIA ICE PLANT

since evaporation must have heat to go on, it cools the surroundings of the liquid which is evaporating. This is important to our health, inasmuch as body temperature is partly controlled by the rate of evaporation of moisture from the skin.

Modern science has learned how to control the cooling of evaporation and how to make it work for man in keeping his foods from spoiling. Artificial ice is made in this way and most of the modern home electric refrigerators work on this principle.

A gas which can easily be turned into a liquid, such as ammonia or sulphur dioxide, is compressed and is then cooled by water running over the pipes. See Figure 53. The liquid ammonia or other substance is then allowed to expand through a valve. As it expands, heat is taken from the surrounding brine, which is cooled. This brine is then pumped through pipes which surround boxes filled with water. The brine becomes cooler than the freezing temperature of the water, and the water freezes.

Figure 54 shows the working parts of a modern electric refrigerator. The coils in which the liquid evaporates are inside the refrigerator, and thus the heat is taken from the inside.

The vapors are again drawn into the compressor, compressed to a liquid, and used over.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 13

Clement, Collister, and Thurston, *Our Surroundings*, Chap. 9

Hunter and Whitman, *Science in Our World of Progress*, pp. 58-63; *Science in Our Social Life*, pp. 96-102

Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 10

Pieper and Beauchamp, *Everyday Problems in Science*, Unit 3

Powers, Neuner, and Bruner, *This Changing World*, Unit 2

Skilling, *Tours through the World of Science*, Tour 3

Van Buskirk and Smith, *The Science of Everyday Life*, Chap 6

Watkins and Bedell, *General Science for Today*, Chap. 3

Webb and Beauchamp, *Science by Observation and Experiment*, Unit 7 (part)

Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It*, Unit 2

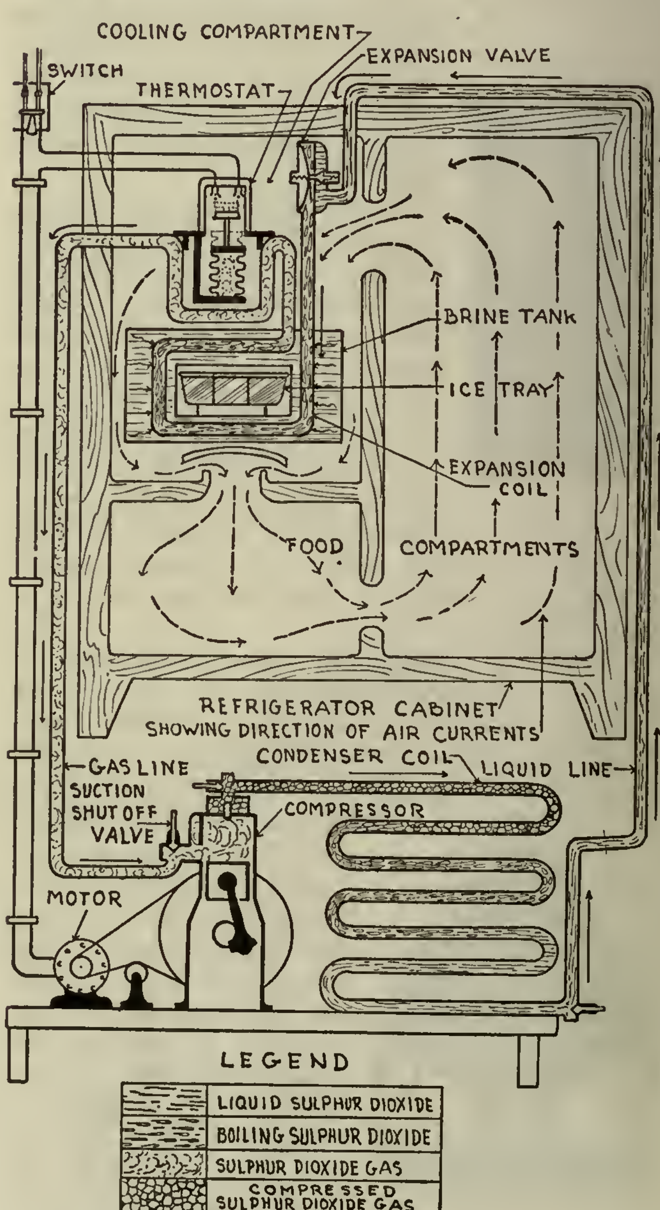
Special references

Barber, *First Course in General Science*

Jameson, *Humidity and Health*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. What evaporation is and the various factors which affect it.
2. How evaporation is of importance to our health.
3. How the principle of evaporation applies to cooling in the electric refrigerator.



Courtesy Kelvinator

FIG. 54. ICELESS REFRIGERATION

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. List three factors which aid evaporation.
2. When water or other (solids, liquids) ____ evaporate, the surroundings are (warmed, cooled) ____ because (heat, cold) ____ aids evaporation.
3. List three factors which hinder evaporation.
4. Boiling is rapid (evaporation, condensation) ____.
5. A simple device that measures relative humidity is called a ____. The dry bulb reads ____ than the wet bulb because ____. Evaporation from the wick is controlled by the ____ in the air.
6. Give several examples of cooling by evaporation.
7. A day that is good for drying clothes should be (warm, cool) ____ and (still, windy) ____ with (low, high) ____ relative humidity.
8. On a certain day the relative humidity was found to be 70 per cent. This means that the amount of moisture actually ____ was only ____ per cent of the ____ which it could ____ at that temperature.
9. Evaporation ____ body temperature because of the ____ effect produced by the ____ of ____ from its surface.
10. In some hot and dry countries water is kept cool by placing it in a porous earthen jar through which some of it can slowly seep. As the film of water on the outside of the jar ____, it takes the needed ____ from the water on the inside of the jar, thus cooling it.
11. From the knowledge gained in the study of this topic, infer why electric fans are used on very warm days. Do fans actually cool the air?

TOPIC 2. WHEN MOISTURE COMES OUT OF THE AIR

SUGGESTED PROBLEMS AND QUESTIONS

1. **What causes moisture to come out of the air?**
2. **What is the water cycle?**
3. **What causes the moisture that comes out of air to assume different forms such as clouds, dew, fog, rain, hail, and snow?**

SUGGESTIONS AND HELPS FOR STUDY

1. You will find that answering the following questions will aid in the solution of the problems. You will be able to answer some of them from your reference study, while others will require experimentation.

a. Problem 1

What is condensation?
In what ways does condensation differ from evaporation?
What is the dew point?
What is the relative humidity at the dew point?
What causes cold water pipes and pitchers of cold drinks to "sweat"?

b. Problem 3

What is dew and what are its causes?
What causes fogs and clouds?
What are the different cloud forms?
Under what conditions are frost and snow formed?
How are sleet and hail formed?

2. You may find the following new words and phrases in this study:

cirrus—a type of feather-like cloud formation usually found at great heights. See Figure 59.
condensation—a change from the vapor state to the liquid state.
cumulus—a type of cloud formation which resembles mountains. See Figure 59.
nimbus—a type of cloud formation which is dark, usually rolling, from which rain or snow may come (Fig. 59).
precipitation—the moisture which comes out of the air as rain or snow.
stratus—a type of cloud formation usually at low levels and appearing in layers or strata (Fig. 59).
water cycle—the round through which water goes in nature in the processes of evaporation and condensation.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 22. How can the dew point be determined?

Secure a bright, shiny cup, such as an aluminum measuring cup, and fill it about two thirds full of cold water. Lower the temperature slowly by adding small bits of ice. Stir the ice and water continually with a thermometer and note the temperature of the water when mist begins to form

FIG. 55

on the outside of the cup. Stop adding ice, allow the mist to disappear, and note the temperature. Again cool by adding ice and note the temperature at which the mist forms. The average of these three readings will be the dew point for that day.

In your notebook[1] record the notes of this experiment and complete the statements given below.

The moisture which condensed on the outside of the cup came from the ____. ____ air can hold more moisture than ____ air. The dew point is the temperature at which the ____ in the air begins to ____. On any day the moisture present in the air is sufficient to saturate it at the ____

[1] See workbook, p. 14.

Experiment 23. How are fogs and clouds produced?

Thoroughly clean and dry a large flask or quart milk bottle. Insert a glass tube about four inches long into a one-hole stopper which fits the flask and connect the glass tube with an ordinary automobile or bicycle pump by means of a rubber tube. Place a small quantity of water in the bottom of the flask and shake in a little chalk dust. Insert the stopper. While holding the stopper tightly in the flask, pump in as much air as you can and then allow the air inside to expand very rapidly by blowing the stopper out.

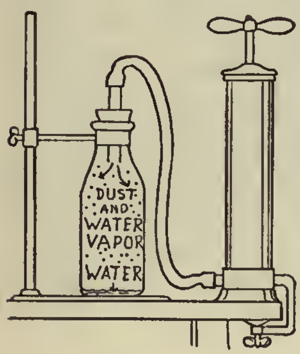


FIG. 56. PRODUCING FOG

In your notebook[1] record the notes of this experiment and complete the statement given below.

The expansion of the air ____ it below its ____ point temperature and some of the ____ formed in the flask as a ____.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What causes moisture to come out of the air? Everyone has experienced those sultry days in summer when water pipes and iced-water pitchers sweat, and when the atmosphere is oppressive and we are very warm and uncomfortable. On such days the air is holding nearly all the moisture possible at the time, and the relative humidity is nearly one hundred per cent. Because moisture from the body cannot evaporate to cool us, we feel hot.

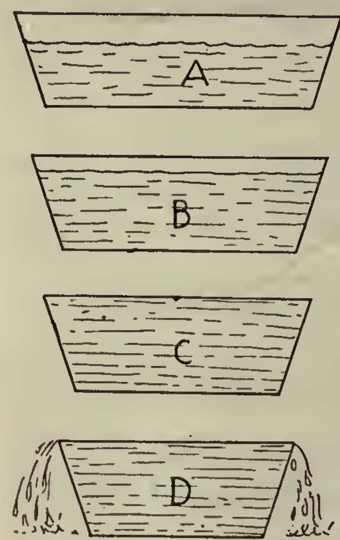


FIG. 57

In the first topic of this unit you learned that at high temperatures the air can hold more water vapor than it can when it is cooler. Experiment 23 in this topic has taught you that some of the water vapor in the air, at any given time, can be made to condense into a liquid if the air is cooled below dew point temperature. This is the temperature where the amount of water present at any time is sufficient to saturate the air or make the relative humidity one hundred per cent. When air is cooled below its dew point, it cannot

[1] See workbook, p. 14.

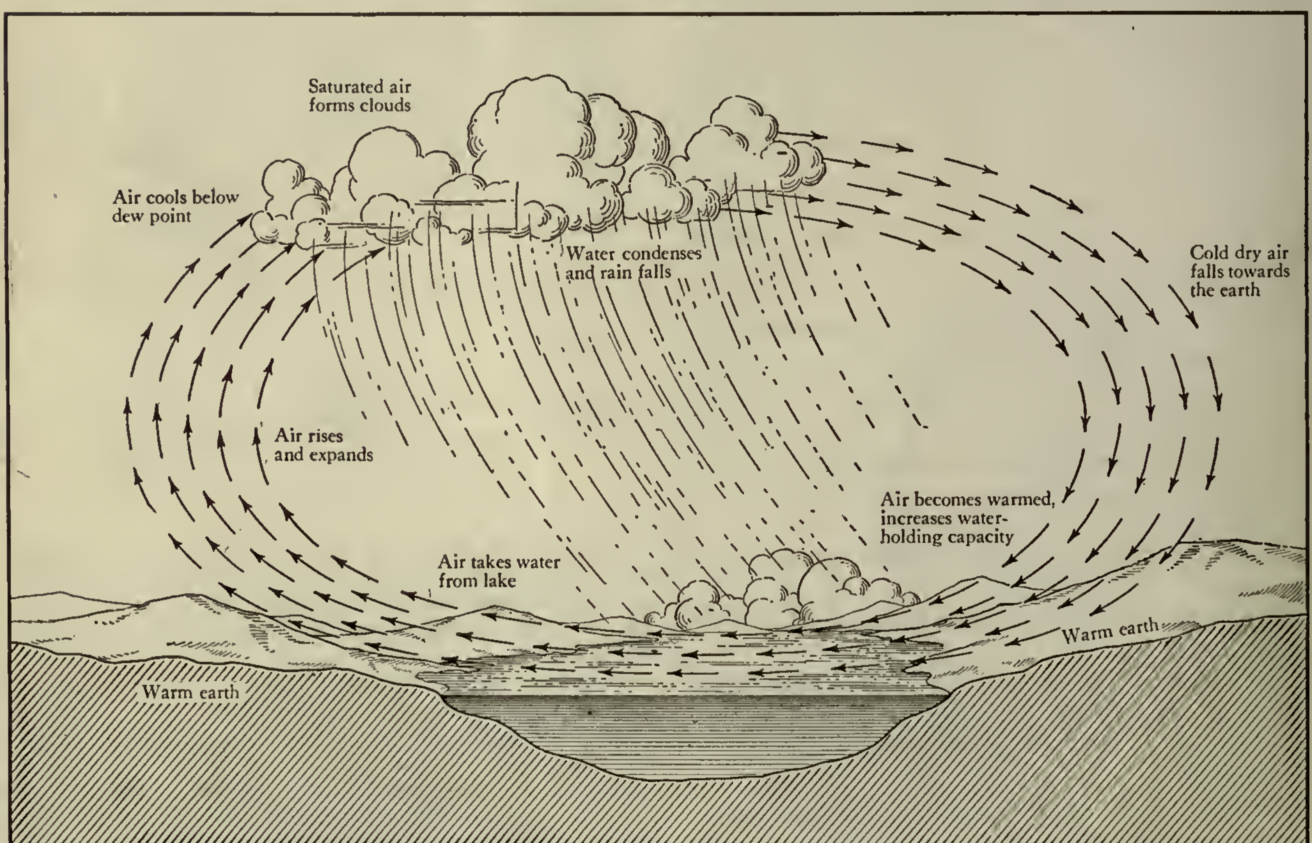
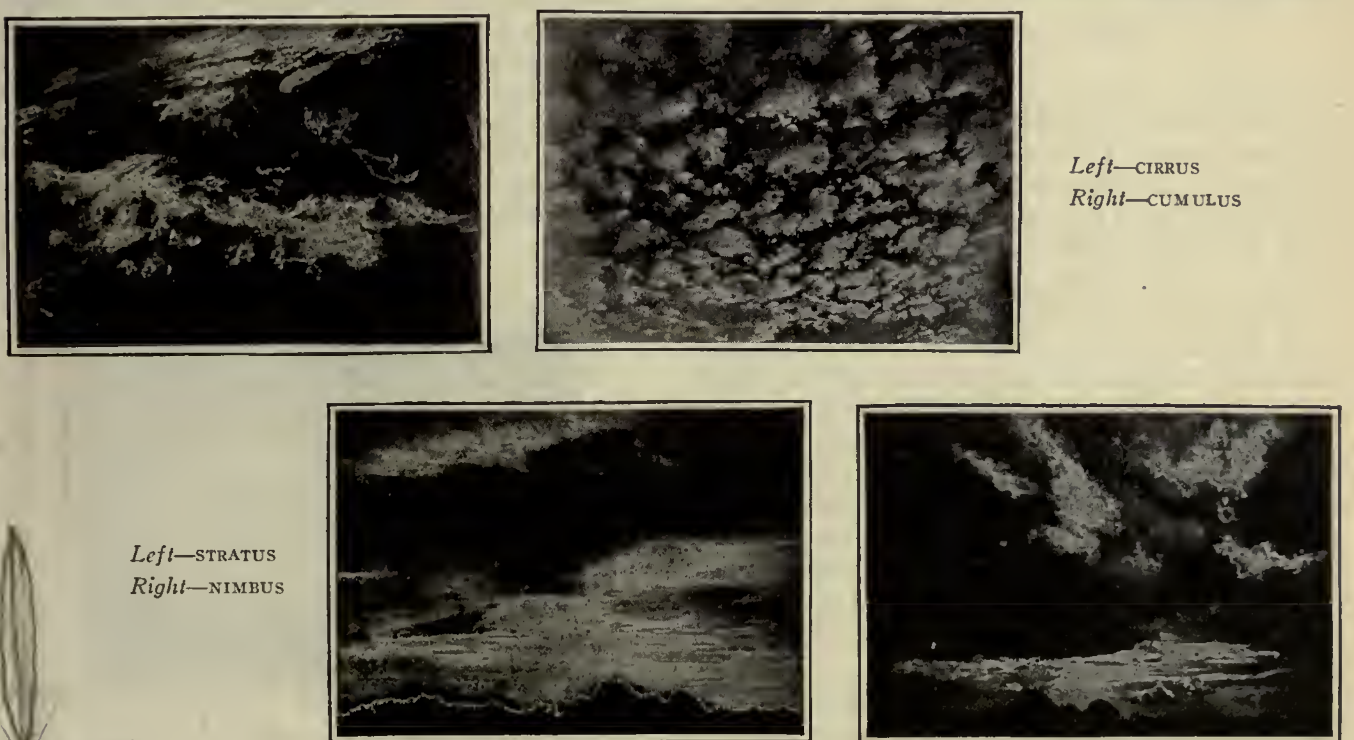


FIG. 58 RAIN CYCLE

hold as much water vapor as before, and some of the water vapor will condense as clouds, fog, dew, or rain.

Water pipes and iced-water pitchers are very cold, and if the air contains a large amount of moisture they cool the air immediately surrounding them below the dew point, and some of the moisture condenses on their cold surfaces.

Let us study Figure 57 to get a clearer picture of this process as it works in nature. The pans represent the water-holding capacity of air at different temperatures. Think of the pan at the top as being about 75 per cent filled. If for some reason this same amount of water were to be poured into the next lower pan and then into the next, it would more nearly fill each one because each is a little smaller than the one above it. Finally a pan would be reached that would just be filled by the amount of water with which we started. See *C* in Figure 57. If the water were to be poured into the next pan some would have to run over the sides as at *D*. This is similar to what happens in nature. At a given temperature the air can hold only a certain amount of moisture, and if on a certain day at that temperature it is holding 75 per cent of its capacity, we say the relative humidity is 75 per cent. If for some reason the air is cooled, the relative humidity will rise because the capacity has decreased. This is like pouring the water from the top pan into the next one below. If the cooling continues, a temperature will be reached where the amount of water present just fills the capacity at that temperature. This is the dew point for that day and any further cooling will cause some of the water to come out just as it runs over when poured into pan *D*. The water may come out as dew, fog, or rain. If this takes place below the freezing point, 32 degrees F., it will be snow or sleet.



Left—CIRRUS
Right—CUMULUS

Left—STRATUS
Right—NIMBUS

FIG. 59. CLOUD FORMS

What is the water cycle? Moisture goes through a complete cycle in nature. By reference to Figure 58 you can see this cycle. The cold dry air, being heavy, falls toward the earth, is warmed, and as a result its water-holding capacity is increased. As it comes in contact with bodies of water, moisture is absorbed and the warm, light, water-laden air begins to rise. As it goes higher the pressure becomes less and less and it begins to expand. Now you will remember from your experiment on fogs that a sudden expansion of air cools it and as this rising air current expands it is soon cooled below the dew point. Some of the moisture will then condense as clouds. If cooling continues, more and more moisture condenses until finally the droplets become too large to float longer and they fall back to the earth as rain. The dry air, now cool and heavy, begins again to fall toward the earth or repeat this never-ending cycle.

What causes the moisture that comes out of the air to assume different forms such as clouds, dew, fog, rain, hail, and snow? Clouds and fogs are caused when the atmosphere is cooled below its dew point. There

are several ways in which this cooling may take place, but the most common is that which results from the expansion of an air mass as it rises. The great white, fluffy cloud masses which every one has seen on a warm summer day are a striking illustration of this principle at work. These clouds usually stop at the peak of an ascending mass of warm, moist air. These air masses are warmed in contact with the earth, and

FIG. 60. MICROPHOTOGRAPH OF SNOW CRYSTALS[1]

as a result of their increased water-holding capacity, they absorb large quantities of moisture. As soon as the mass begins to expand it cools, and soon the moisture begins to condense as a cloud.

Clouds are also formed when wind moves warm moist air into a region of cooler air where the moisture condenses when the cooling has proceeded below the dew point. The well known fogs off Newfoundland are a result of such a cause. Air which has been warmed by the Gulf Stream becomes moisture laden and then blows into the region of the cold Labrador Current.

The fogs which frequently occur over certain cities, of which London, England, is the best known, are partly condensed moisture and partly smoke. They hang over an area because atmospheric conditions are such as not to move them out. Such fogs as these are a menace not only to trade and shipping but also to health.

There are many types of clouds. Scientists recognize several classifications of cloud forms. Some of these are illustrated in Figure 59.

Cirrus clouds are wisp-like, delicate, and feathery, usually white and at great altitudes. At times cirrus clouds are composed of ice crystals because of the low temperatures at the high altitudes in which they are formed.

Stratus clouds, as their name implies, are those which are formed in layers. These clouds are usually formed near the earth and somewhat resemble fog in their appearance. The dark days of late fall and winter are often caused by stratus clouds.

Cumulus clouds are the familiar "fluff-balls" or "wool packs" seen on warm summer days. These cloud forms are usually very thick at the bottom and taper to a peak at the top. At times it is not unusual to see cumulus clouds that have been torn by the wind into cotton-like masses which may cover large areas.

Nimbus clouds are dark, irregular masses from which rain or snow usually falls. They usually have very ragged edges and are almost shapeless.

Dew and frost result when the air near the earth is cooled below its dew point. On still, clear nights which are cool, the earth cools off very rapidly, losing its heat by radiation. Soon the air immediately in contact with the earth has been cooled below its dew point, and the moisture begins to condense on grass and other objects. This moisture is known as dew. Dew is formed only when the temperature is above the freezing point of water, that is 32 degrees Fahrenheit. If the air is cooled below this temperature the moisture is then deposited as frost. Frost forms are often fantastic and beautiful. Snowflakes, too, may have very beautiful shapes. Many photographs of snowflakes have been made and many varied appearances found, but always they conform to some type of a six-sided pattern or hexagon. Figure 60 shows some types of snow crystals.

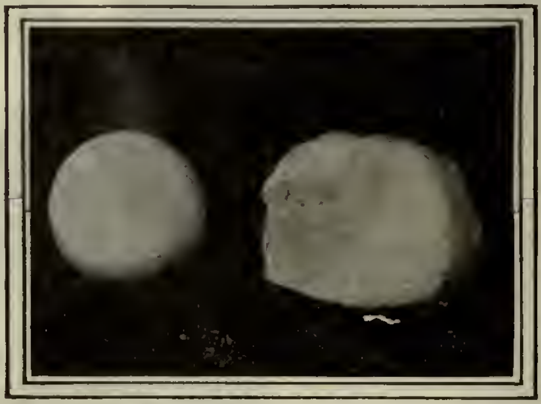


FIG. 61. HAILSTONES BESIDE TENNIS BALL

FIG. 62. CROSS SECTION OF A HAILSTONE

At times in a storm raindrops may pass through a layer of air which is below the freezing point. They are frozen into ice pellets and fall to the ground as sleet. Hail results when raindrops are frozen and then caught in an upward current of air which causes the ice pellets to melt on the surface. As they again fall through the colder layer of air another layer of ice is added. This process may repeat several times, building up several layers of ice in the hailstone. Figure 62 shows the layered structure of a hailstone.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 13
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 9

[1] From *Snow Crystals* by Bentley and Humphreys. © McGraw-Hill Book Company. Reproduced by permission.

Hunter and Whitman, *My Own Science Problems*, pp. 82-86; *Science in Our World of Progress*, pp. 58-64

Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 10

Pieper and Beauchamp, *Everyday Problems in Science*, Unit 3

Powers, Neuner, and Bruner, *This Changing World*, Unit 2

Skilling, *Tours through the World of Science*, Tour 3

Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 6

Watkins and Bedell, *General Science for Today*, Chap. 3

Webb and Beauchamp, *Science by Observation and Experiment*, Unit 7 (part)

Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It*, Unit 2

Special references

Barber, *First Course in General Science*

Jameson, *The Mountains of Cloudland and Rainfall*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of the conditions which cause moisture in any form to come out of the air.
2. How condensation differs from evaporation.
3. How evaporation and condensation working together form a water cycle in nature.
4. The differences between the various forms of moisture, such as dew, fog, rain, snow, and frost.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. When condensation takes place a ____ changes to a ____.
2. Relative humidity is a comparison of the amount of water vapor in the air with the amount needed to ____ it at the same temperature.
3. The dew point is that temperature at which (water vapor, air) ____ begins to (condense, evaporate) ____.
4. The relative humidity is always one hundred per cent at the (freezing point, dew point) ____.
5. Why does dew always form close to the earth?
6. Cirrus clouds are formed at (low, high) ____ levels.
7. From what kind of clouds does rain usually come?
8. When a vapor condenses it (takes in, gives out) ____ heat.
9. Explain in detail what is meant by the water cycle in nature.
10. Fog is formed when some of the ____ near the earth is cooled below the ____ point and ____ of the moisture takes place.
11. Explain in detail what causes rain.
12. Frost is formed by the ____ of moisture when the ____ point is below the ____ point of water or 32° Fahrenheit.
13. Drops of moisture are often formed on the outside of water pitchers and cold water pipes in summer because the surrounding ____ is cooled below its ____ and some of the moisture ____.
14. On a cold day frost is often formed on the inside of a window pane. Infer the cause of this.
15. Modern electric refrigerators must frequently be "defrosted" of the ice which accumulates on the coils inside the box. Infer a cause for this.

TOPIC 3. WINDS AND WEATHER

SUGGESTED PROBLEMS AND QUESTIONS

1. **What happens to air when it is heated or cooled?**
2. **What causes winds?**
3. **What are cyclones and anticyclones? From what direction do weather changes come?**
4. **What causes land and sea breezes and the various winds of the world?**

SUGGESTIONS AND HELPS FOR STUDY

1. The answers to the following questions will aid in the solution of the problems. You will be able to answer some from your reference study and some from your own experience, while others will require experimentation for their answer.

a. Problem 1

What change is there in the volume of air when it is heated?

How do warm air and cold air compare in weight?

How would the pressure, due to weight, exerted by cold air compare with that exerted by warm air?

b. Problem 2

Do all portions of the earth's surface always have the same temperature? What are the conditions which might cause a difference?

What change would occur in a body of warm air next to or surrounded by a body of cooler air?

c. Problem 3

What conditions cause a difference in air pressure on different parts of the earth's surface?

What is happening to the air over a low-pressure area?

What is happening to the air over a high-pressure area?

How are the winds blowing over a low-pressure area? Why?

In what wind belt is North America located?

In what direction is the earth rotating?

Would weather changes come from the west in South America?

2. You may find the following new words and phrases in this study:

anticyclone—a large mass of slowly whirling cool air which is descending; a high-pressure area.

clockwise—turning in the same direction as the hands of a clock.

counter-clockwise or *anti-clockwise*—turning in the direction opposite to that of the hands of a clock.

convection currents—currents set up in gases or liquids due to a difference in temperature and therefore in the weight of equal volumes of different parts of the gas or liquid.

cyclone—a mass of slowly whirling warm air which is rising; a low-pressure area.

doldrums—large masses of heated ascending air near the equator. These are sometimes called the equatorial calms.

high—a large mass of descending air in a region of high barometric pressure or an anticyclone.

low—a large mass of ascending warm air in a region of low barometric pressure or cyclone.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 24. What happens to air when it is heated?

Grease a solid rubber stopper and place it in the mouth of a flask. Heat the flask gently over a very low bunsen flame. Explain the result. Through a one-hole stopper placed in a small flask, insert a one-foot length of glass tubing. Place the end of the tube under the surface of some water in a beaker. Gently heat the flask and observe what happens. Allow the flask to cool with the tube still under water.

FIG. 63

In your notebook[1] record the notes of this experiment and complete the following statements.

When the flask was heated the stopper ____. When the second flask was heated ____ through the water. When it was allowed to cool ____ entered the tube. This shows that ____ caused the air to ____ and drove as much of it from the flask as there was water which ____ when the flask was allowed to cool.

Experiment 25. Which is heavier, warm air or cold air?

Suspend two flasks of 400 or 500 cubic centimeter capacity from the arms of a balance or from the ends of a yard stick pivoted in the center. If they do not quite balance, place sand in the lighter one until it weighs the same as the other. Gently heat one of the flasks and carefully observe what happens. Allow to cool and heat the other flask.

[1] See workbook, p. 15.

In your notebook[2] record the notes of this experiment, complete the following statements, and make the required drawing.

The air in the flask that was heated became (heavier, lighter) ____. The air in the flask that was cool seemed to be ____. (A diagram should be drawn to show their position.) When the other flask was heated it ____ and the cool one ____. This experiment would seem to indicate that ____ air is lighter than ____ air.

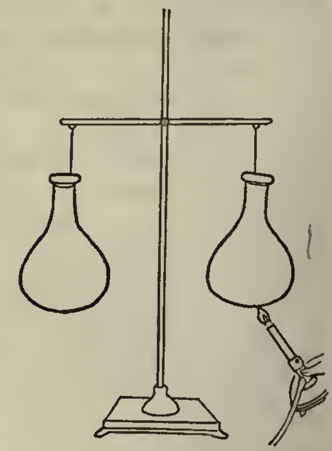


FIG. 64

Experiment 26. What causes winds to blow?

From a tight box about one foot long, seven inches high, and five inches wide, make a wind box similar to the one shown in Figure 65. Groove the front edge so that a glass may be placed in it. Cut two holes in the top and insert lamp chimneys or mailing tubes. Place a short candle under one of the chimneys and hold a smoking paper over it. Now hold the smoking paper over the other chimney. Trace the air current in each chimney by the smoke. Trace the air current direction inside the box by observing the smoke. A good smoke paper can be made by soaking strips of blotting paper in potassium nitrate and allowing them to dry.

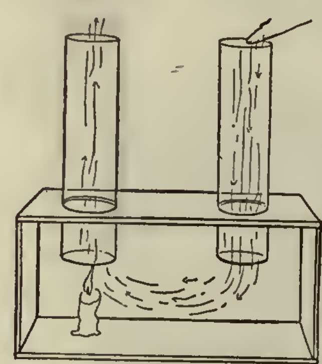


FIG. 65

In your notebook[3] record the notes of this experiment and complete the following statements.

The air current rose in the (cool, warm) ____ chimney and fell in the (cool, warm) ____ chimney. Inside the box the air moved toward the (warm, cool) ____ chimney. Using the data from the two previous experiments I should explain this experiment in the following way. When air is heated it ____ and grows (heavier, lighter) ____. The heated air in the chimney over the candle (expanded, contracted) ____, became (heavier, lighter) ____, and was pushed up by the (warm, cool) ____ air in the other chimney which was (rising, falling) ____ because of its ____ weight.

If on a certain day it was cloudy and cool over the Rocky Mountain states while it was sunny and warm over the states of the Mississippi valley, predict what would probably result on the basis of your experiment. Record in your notebook.

Experiment 27. How do the winds blow about a low and high pressure area?

Carefully study the weather maps (Fig. 66) and find areas marked "Low" on them. Find others marked "High."

[2] See workbook, p. 15.

[3] See workbook, p. 16.

The arrows point the direction of the winds in each case.

In your notebook show by an arrow the wind direction about a "low" and the wind direction about a "high." Complete the following statement.

Compared with the motion of the hands of a clock, the winds about a "low" blow in the ____ direction and about a "high" in the ____ direction.

Experiment 28. In what direction do weather changes move?

Study the first of the weather maps shown in the three-day series (Fig. 66) and locate a low-pressure area over some western state and a "high" over some other portion of the country. Study the second map of the series and determine what movement of each has taken place. Study the third map and see if you can reach a conclusion regarding the question of this experiment.

In your notebook complete the following statement.

From this experiment I am able to conclude that low- and high-pressure areas travel across the country from ____ to ____. RAIN

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What happens to air when it is heated or cooled? Nearly everyone is familiar with the fact that the air at the top of a room is warmer than near the floor; that air over a radiator or register rises and that fresh air from a window comes in at the bottom while the warmer, used air goes out near the top. These conditions all result from a difference in weight of cold and warm air.

When any gas, like air, is heated, it expands or grows larger and as a result gets lighter. This causes other parts of the gas which are cooler and heavier to rush in and push the lighter, heated portions upwards. This sets up currents in the air called *convection currents,* for as the warmer air rises and the cooler air sinks a circulation is brought about. We make use of these convection currents in warm-air heating systems. They may also be caused in a liquid such as water when parts of it are unequally heated. Convection currents are also used to circulate the water in hot-water heating systems.

What causes winds? As the sun shines on the earth it warms some parts more than others. Water warms up more slowly than land and holds its heat longer. Some places on the earth's surface absorb more of the sun's heat than others. Air which is in contact with these unequally heated portions of the earth's surface becomes

FIG. 66. WEATHER MAPS FOR THREE CONSECUTIVE DAYS

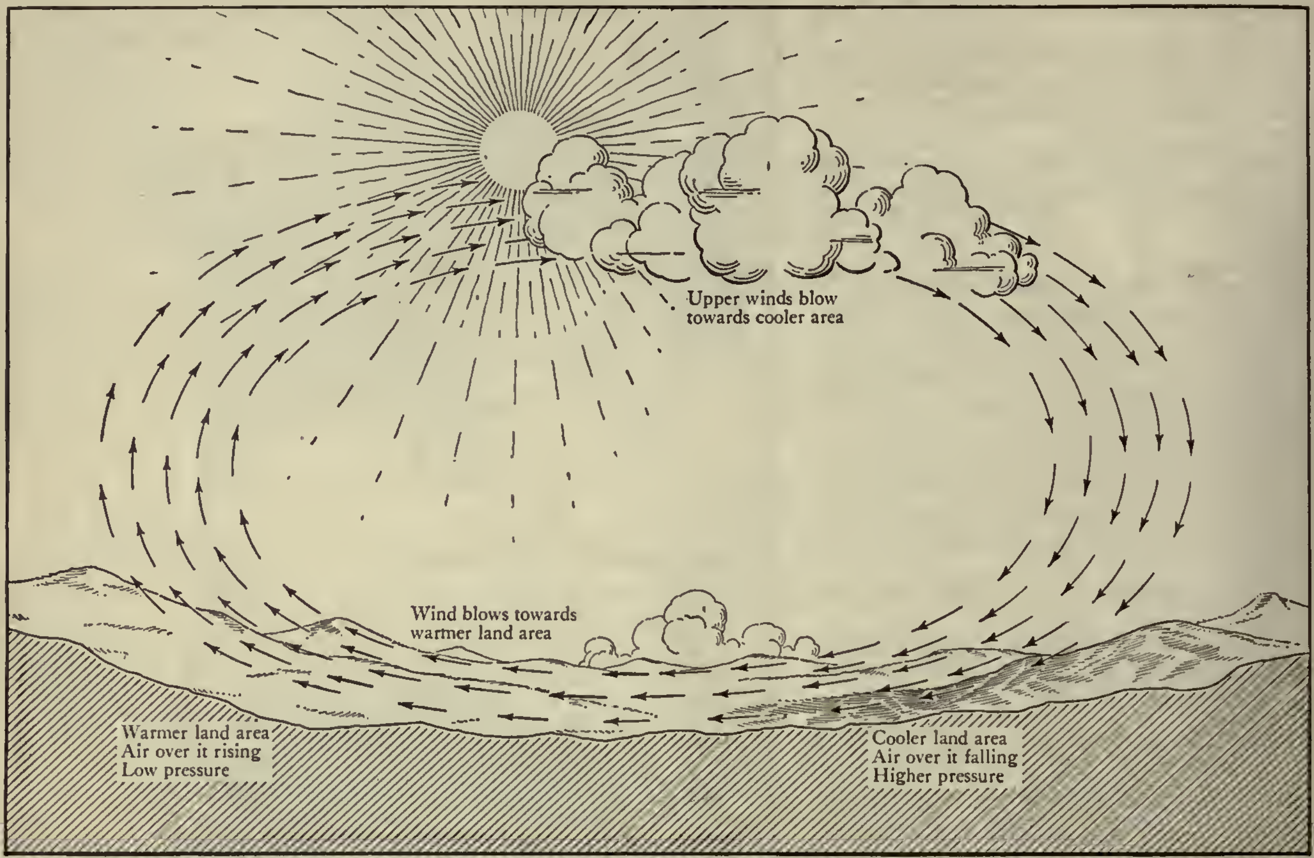


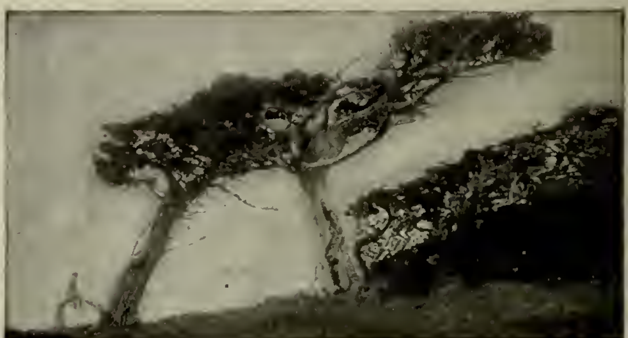
FIG. 67. WHY WINDS BLOW

unequally heated, and that which is warmer is pushed up by the heavy, cooler air which rushes in, and thus huge convection currents are set up. Near the earth the movement is towards the point where the air is heated, but at higher altitudes the direction is away from the rising warm air column and toward the falling cold air. A study of Figure 67 will make this clear to you.

What are cyclones and anticyclones, and from what direction do weather changes come in this country? If a barometer were read over an area where the air is warm it would be found to read less than where it is cooler. The place where the reading is lower is called a low-pressure area or *low* and where it is higher, a high-pressure area or *high*. Your experiment has taught you that winds blow from a "high" toward a "low," and if you remember from a previous study that warm air holds more moisture than cold air, you can see why bad weather is usually associated with low-pressure areas. The warm, moist air is pushed up by the colder, dry air to higher levels where it expands, cools, and loses some of its moisture.

The air over a "low" does not rise straight up but has a spiral motion in a direction opposite to the motion of the hands of a clock. This direction is commonly spoken of as *counter-clockwise*. These winds blow in toward the center of the low-pressure area. Also the winds about a "high" are spiral in a *clockwise* direction, blowing away from its center, as your study of the weather maps and the diagram you made have taught you. These spiral winds are caused by the rotation of the earth combined with the rising and falling air currents. The name *cyclone* is given to low-pressure areas and the name *anticyclone* to high-pressure regions.

Low- and high-pressure areas, varying from 400 to 1000 miles in diameter, move across North America generally from west to east, bringing our changing weather conditions. The movement is from the west toward the east because this continent lies in the wind belt called the *prevailing westerlies*. Figure 68 shows how trees are sometimes affected by the prevailing winds of a locality.

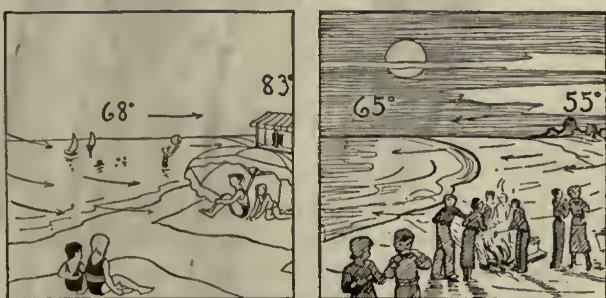


Courtesy Taylor Instrument Company

FIG. 68. THE WORK OF PREVAILING WINDS

What causes land and sea breezes and the various winds of the world? Anyone who has been near large bodies of water knows that during the day breezes blow in from the water to the land and that at night conditions are reversed. As has already been stated, the earth warms up more rapidly than the water; during the day the warmer air over the land is pushed upwards by the cool, heavy air over the water as it comes in, making a sea breeze. Not only does the earth warm up more rapidly during the day, but it also loses its heat more rapidly at night. The land is soon cooler than the water, and the air over it begins to fall and push the warmer air over the water upwards, making a land breeze toward the sea. A study of Figure 69 will make this clearer to you.

Since the earth is heated more in regions near the equator, the air over the tropics is warmer and lighter than that over the cold polar regions. This cool polar air comes in under the tropic air and pushes it upward. This sets up vast convection currents blowing in from the north and south polar regions toward the equator. These currents are called the *trade winds* and are among the most important of the earth.



DAYTIME—TOWARD LAND NIGHT—AWAY FROM LAND

FIG. 69

Because of the rotation of the earth these air currents do not run in a north and south direction, but are deflected so that north of the equator they blow from northeast to southwest and south of the equator from southeast to northwest. Figure 70 shows this clearly.

Sailing vessels formerly took advantage of the trade winds in sailing to America by way of the southwest trades and returned to Europe in the belt of the prevailing westerlies.

The monsoon winds of the Indian Ocean are caused by the unequal heating of land and ocean areas. The summer weather of India and the countries adjacent to the Indian Ocean is very hot. The air over these land areas therefore becomes heated, expands as a result, and starts to rise. The cooler air from the ocean begins to move in, creating a wind blowing from the water. These winds are very moist, and as a result, the summer monsoons bring plenty of rain. In the winter months the land areas are cooler than the water, and therefore winds are set up which blow toward the ocean. Can you predict whether these winds would be moist or dry, and give a reason for your prediction?

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 13
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 9
Hunter and Whitman, *Science in Our World of Progress*, pp. 67-70
Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 10

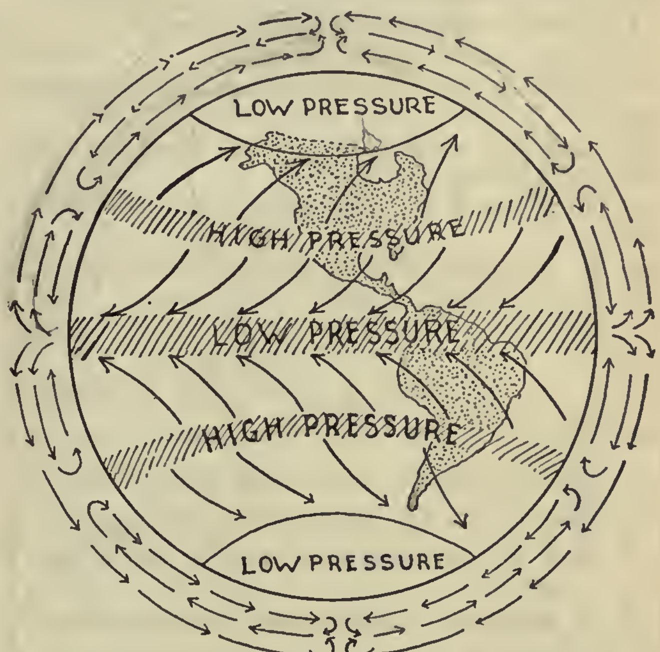


FIG. 70. WINDS OF THE WORLD

Outside arrows represent currents in the upper atmosphere.

Pieper and Beauchamp, *Everyday Problems in Science*, Unit 3
Powers, Neuner, and Bruner, *This Changing World*, Unit 2
Skilling, *Tours through the World of Science*, Tour 3
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 6
Watkins and Bedell, *General Science for Today*, Chap. 3
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 7 (part)
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It*, Unit 2

Special references

Brooks, *Why the Weather?*
Barber, *First Course in General Science*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The conditions which cause unequal heating of the air over the earth.

2. The relation of the unequal heating of the air to winds.

3. The relation of unequal heating of the air to low- and high-pressure areas.

4. Why winds blow in different directions about low- and high-pressure areas.

5. The causes and results of the various winds of the world.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements and answer the questions.

1. Warm air is ____ than cold air.
2. Winds blow because of a difference in ____ of various parts of the atmosphere due to a difference in ____.
3. In what wind belt does North America lie?
4. A cyclone is a ____ pressure area.
5. Winds blow in a ____ direction about a high-pressure area.
6. Air over a low-pressure area is (warm, cool) ____ and (rising, falling) ____.
7. Winds blow in a ____ direction about a low-pressure area.
8. Air over a high-pressure area is (warm, cool) ____ and (rising, falling) ____.
9. What are some of the conditions that cause unequal heating of the earth's atmosphere?
10. A tornado is sometimes spoken of as a cyclone. Is this correct? Explain.
11. Weather changes come from the west in North America because it lies in the ____ known as the ____.
12. Convection currents are movements set up in ____ or ____ due to a difference in density caused by ____ heating.
13. An observer noticed that on a certain day the wind was blowing steadily from the southeast toward the northwest. How did the air pressure at the point of observation compare with the pressure at some point northwest of the observer? At which point was the air warmer? Was the air rising or falling at the point of observation?
14. Aviators frequently fly at altitudes where they can take advantage of so-called "tail winds." Can you establish a reasonable cause for such winds above the earth on the basis of the facts which you have learned in this study?
15. What cause would you establish for what the aviator calls "bumpy air"?
16. Aviators frequently strike air pockets. On the basis of the facts learned in this topic, establish a reasonable cause for these.

TOPIC. 4. HOW THE WEATHER MAN PREDICTS THE WEATHER

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is the weather lore of your locality?**
2. **How are thermometers used in foretelling weather?**
3. **Of what value are barometers in weather forecasting?**
4. **Of what importance are winds in weather prediction?**
5. **How is rainfall measured?**
6. **How is the weather map made, and for what is it used?**
7. **What are some of the recent advances in weather forecasting?**

SUGGESTIONS AND HELPS FOR STUDY

1. The answers to the following questions will prove helpful in the solution of the problems suggested above. Some of these can be answered by experiment, others by reading.

a. Problem 1

How much weather lore do you know? Make a list in your notebook. Secure as many from your community as possible. Some are given below.

Weather Lore

1) "Mackerel sky never leaves the ground dry."

2) "When the wind veers against the sun,
Trust it not, for back 'twill run."

3) "When the glass falls low, prepare for a blow;
When it rises high, let all your kites fly."

4) "When the wind is in the east,
'Tis good for neither man nor beast."

5) "If hoar-frost comes on mornings twain,
The third day surely will have rain."

6) "If the sun goes pale to bed,
'Twill rain tomorrow, it is said."

7) "If Candlemas Day is bright and clear,
There will be two winters in the year."

8) "If March comes in like a lion it will go out like a lamb."

9) "If on the trees the leaves still hold,
The coming winter will be cold."

10) "Evening red and morning gray
Help the traveler on his way."

11) "Evening gray and morning red
Send the traveler wet to bed."

12) "Long foretold, long last,
Short notice, soon past."

b. Problem 2

How does the maximum-minimum thermometer aid the weather man?

c. Problem 3

How may low- and high-pressure areas be detected?
How does the mercury barometer work?
How does the aneroid barometer work?
What weather conditions usually accompany a high-pressure area? A low-pressure area?
How can a barometer be used to fortell weather conditions?

d. Problem 4

How are winds studied?
What information regarding weather do they give us?

How are clouds used in forecasting weather?

e. Problem 5

What is relative humidity?

How is relative humidity measured?

f. Problem 6

How are weather maps made up?

Study the weather maps in Figure 66 and find out what each kind of marking on them means.

In what general direction do storms move across the United States?

What is an isobar?

What is an isotherm?

For what is the weather map used by industries? By farmers? By fruit growers? By shippers?

From the weather maps in Figure 66 determine the type of weather in your locality on each of the days represented.

2. You may find the following new words and phrases in this study:

centigrade—a temperature scale made on the basis of 100 degrees; on this scale water freezes at 0° and boils at 100°.

Fahrenheit—a temperature scale on which the freezing point of water is 32 degrees and its boiling point 212 degrees.

isobar—a line on a weather map drawn through points of the same barometric pressure.

isotherm—a line on a weather map drawn through points of the same temperature.

3. In the study of this topic the daily weather map should come to your school. Apply to the nearest city where it is printed and state for how long a period you would like it sent.

4. Make a class book of weather lore and try to find a scientific principle upon which each saying might be based. Ask your instructor.

5. Read the barometer, watch the cloud forms and the shifting of the winds, and try to forecast the weather for yourself. This will prove very interesting and worth while.

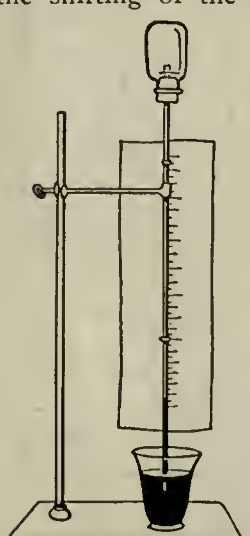


FIG. 71

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 29. How does the air thermometer work?

Fit a one-hole stopper to a small flask and insert a piece of glass tubing about eighteen inches long. Place the lower end of the glass tubing under the surface of some colored water in a beaker. With a Bunsen burner heat the flask gently until several bubbles of air have escaped. Allow the flask to cool to room temperature and mark the position of the liquid in the tube. Mount the flask and tube on a ring stand and, on a paper scale fastened behind the liquid column, mark the different levels of the liquid at different room temperatures.

An electric light bulb which has had the brass shell removed and the stem filed out may be used as a flask.

Summarize your observations and what you have learned in a clear statement in your notebook.[1]

Experiment 30. How does the liquid thermometer work?

Use a small flask or an old electric light globe for a thermometer bulb and place a one-hole rubber stopper in its top. Through the one-hole stopper place a two-foot length of glass tubing of small bore. Fill the bulb with water which has been colored with ink. The bulb should be filled to such a point that when the stopper and tube are replaced the water will rise several inches in the tube. Support the water thermometer on a tripod or ring stand and heat the bulb gently. Observe the water level in the tube closely and record your observations below. After heating has continued for some time allow the water to cool to room temperature. After comparing with a mercury thermometer mark this point on a scale fastened behind the tube.

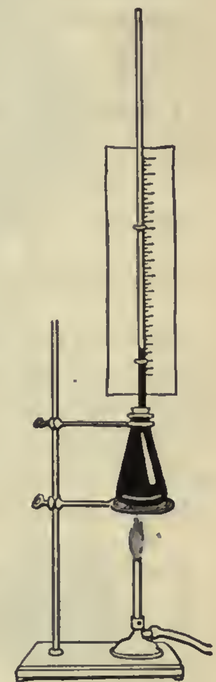


FIG. 72

In your notebook[2] record the notes of this experiment and complete the following statements.

When the flask was first heated the water level in the tube ____. Afterward it began to ____. When the water is ____ it (expands, contracts) ____ and rises in the tube. When the temperature falls the water ____ and the level in the tube again ____.

Experiment 31. How are weather maps read?

Carefully study the three weather maps in Figure 66. Note the solid lines and the broken lines in all three of the diagrams. Learn how the temperature of a given place is indicated and what an isotherm is. Learn how the barometric pressure of a given point is told, what isobars are, and how they are drawn. How are weather conditions of a certain locality on the map indicated? How is wind direction marked? Study the weather conditions as indicated in several low-pressure areas. What is the pressure at the center? How does the pressure change as you go away from the low? What is the general wind direction about the low-pressure area? Study the weather conditions as indicated in several high-pressure areas and answer the same questions as before.

In your notebook[3] carefully summarize what you have learned from this investigation, giving information on each of the questions suggested in the directions above.

Experiment 32. How do cyclonic and anticyclonic areas travel across the country?

Locate a low-pressure area in the western part of the

[1] See workbook, p. 18.
[2] See workbook, p. 19.
[3] See workbook, p. 19.

United States on the first weather map in Figure 66. Find the same area on the maps of the next two consecutive days.

In your notebook[1] complete the following statements and comply with the instructions.

On the first day the low-pressure area was over the state of ____. On the second day it had moved ____ and was then over the state of ____. The third day the low had moved farther ____ and was over ____. The kind of weather which accompanied this low-pressure area was ____ and ____, as indicated by the markings on the map.

Study the map (Fig. 73) showing the average paths of high and low pressure areas over the United States and Canada. List in your notebook the conclusions that may reasonably be reached on the basis of the data shown.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. How can a wind vane be made?
2. How can a weather map be made? (See Barber, *First Course in General Science.*)
3. Make an investigation of the various types of cloud forms and observe them from day to day.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is the weather lore of your locality? Every community has its weather prophet. He is supposed to be able to tell in advance whether the next winter is to be cold or mild, long or short, and whether the summer will be dry or wet. Many people still believe in signs and omens and will plant certain crops only when the moon is new or in a particular phase. There is hardly a hamlet in the world where weather prediction by signs is not engaged in. In fact, so common is the practice and so long has it gone on that many weather signs have been made into little rimes so that they may be more easily remembered. These are called *weather lore.*

There is little or no scientific basis for believing the long distance weather telling of local prophets and much of the weather lore. There are, however, some weather sayings which have grown up as a result of a long period of observation and which are fairly good indicators of the weather. In fact, some of these have a certain amount of scientific foundation which, of course, is unknown to most of the users. Study all the weather lore available and try to find sayings which may have some scientific foundation.

How are thermometers used in foretelling weather? In the study of the topic about winds you learned that the movement of great air masses over the earth was caused by the difference in heating of various parts of its surface. Thus, the temperature of the air at two places, taken at the same time, will give a clear idea of the movement and currents of air masses. Also, in the study of a previous topic you learned that the water-holding capacity of the air is influenced

[1] See workbook, p. 19.

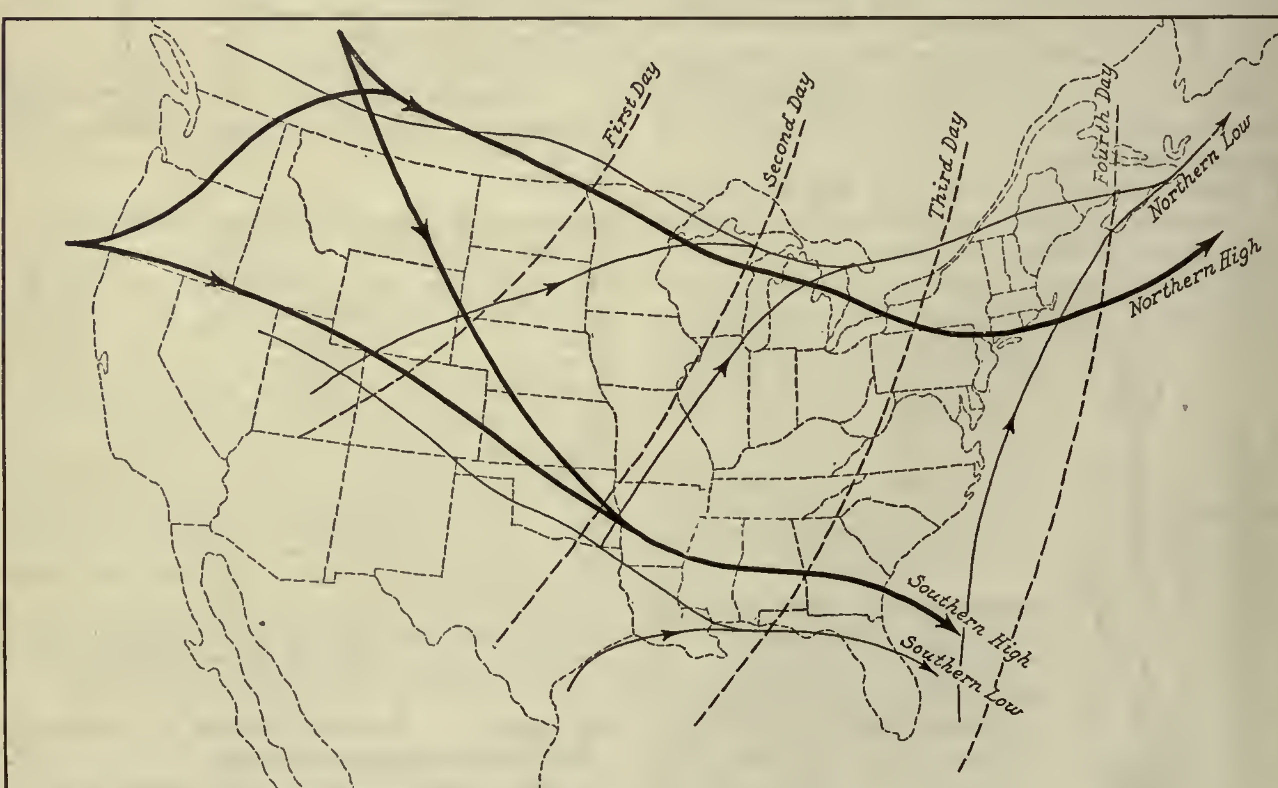
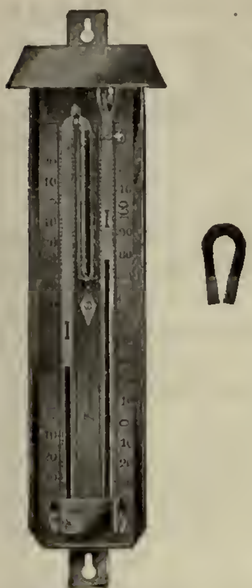


FIG. 73. USUAL PATHWAYS OF HIGH AND LOW PRESSURE AREAS
The heavy lines indicate "highs" and the lighter lines indicate "lows."



Tycos
FIG. 74. MAXIMUM-MINIMUM THERMOMETER

by its temperature, warm air being able to hold more moisture than cold air.

At the U. S. Weather Bureau stations temperature readings are taken on maximum-minimum thermometers, one type of which is shown in Figure 74. The little steel index riders are carried by the mercury to the highest and lowest temperatures for the day. Such a thermometer must be set each day by means of a magnet as illustrated.

On the weather map dotted lines, called isotherms, are drawn through localities on the map which have the same temperature. In general lower temperatures prevail near high-pressure areas and higher temperatures near low-pressure areas.

Of what value are barometers in weather forecasting? The barometer enables one to tell at any time how the pressure of the air is changing and when a "low" or "high" is passing. Since pressure differences in the atmosphere are the chief determiners of weather, the aneroid barometer has become a household device in many places. The one shown in Figure 75 is a common type used in offices and homes.

Of what importance are winds in weather prediction? From the study of a previous topic in this unit, you have learned that the United States lies in the wind belt known as the prevailing westerlies. These warm winds blow over the Pacific Ocean and pick up large quantities of moisture. As they blow over the western slope of the Rocky Mountains, they rise, the air expands and is cooled, and much of the moisture falls as rain or snow. This makes for the ample rainfall in all Pacific Coast states, but is also the cause of the dryness and aridness of the eastern slopes of the Rockies.

These same winds continue eastward across the continent, bringing us the succession of high- and low-pressure areas which we know as weather changes. "Lows" and "highs" follow one another across the continent with speeds ranging between 250 and 1000 miles a day. As a low-pressure area approaches and passes a given locality some interesting changes take place. The following wind observations are given on all United States weather maps: "When the wind sets in from points between south and southeast and the barometer falls steadily, a storm is approaching from the west or northwest and its center will pass near or north of the observer within 12 to 24 hours with the wind shifting to northwest by way of southwest and west. When the wind sets in from points between east and northeast and the barometer falls steadily a storm is approaching from the south or southwest and its center will pass near or to the south or east of the observer within 12 to 24 hours with wind shifting to northwest by way of north. The rapidity of the storm's approach will be indicated by the rate and the amount of the fall in the barometer."

Tycos
FIG. 75. STORMOGUIDE

Tycos
FIG. 76. ANEMOMETER

Thus it is clear that by carefully observing the wind direction and its changes one can accurately predict the position of the center of a low-pressure area.

Rain, snow, or generally unfair weather accompanies a "low" because the air over it is rising and

being cooled by expansion so that much of the moisture in a low-pressure area may fall as rain or snow. On the other hand, the falling dry air over a high-pressure area tends to absorb moisture, thus clearing the air of clouds and making it invigorating. High-pressure areas bring fair weather generally.

Figure 76 shows an anemometer used at the U. S. Weather Bureau for measuring the velocity of winds.

Rainfall is measured by rain gauges. Every weather bureau station has a rain gauge for measuring the amount of rainfall. There are many types, the one shown in Figure 77 being generally used. Here the top is about eight inches in diameter and is funnel-shaped. The rain is collected in the funnel and then drips through the small curved pipe into the cup below. To determine the number of inches of rainfall the contents of the cup are poured into the measuring graduate which is marked off in hundredth parts of an inch.

Tycos

FIG. 77. RAIN GAUGE

How is the weather map made and for what is it used? The making of the weather map requires the coöperation of nearly three hundred branch stations and several thousand observation points scattered over the United States and Canada. Each day at 8 a.m. and 8 p.m., Eastern Standard Time, measurements are made of the temperature, pressure, relative humidity, wind direction, wind velocity, and general weather conditions at these stations. These are telegraphed in code to Washington, D.C., and other forecast centers in the country, where they are recorded and studied. From these data the weather predictions for the next twenty-four hours are made. At some key stations the data are printed in a weather map and sent out to cities, towns, and important industries in that area.

Few of us realize the great importance of the Weather Bureau, but when we stop to consider the value of advance knowledge of a cold wave, a frost, or a destructive hurricane, we can better see how difficult it would be to dispense with it.

The Weather Bureau also publishes a "Monthly Weather Review," which contains a summary of the various weather factors for the month.

What are some of the recent advances in weather forecasting? A recent study of the reliability of the forecasts of the Weather Bureau reveals that it is correct about eighty per cent of the time. However, with the increasing importance of weather forecasting to aviation, the authorities in charge desire to make the reports even more reliable. The Science Advisory Board of the government has completed plans to join the aerological services of the army and navy with those of the Weather Bureau for the adoption of the air-mass-analysis method of weather study. This new method, worked out over several years of careful study by scientists, would not displace the present method, but would serve to make it more effective and probably more reliable.

Heretofore most of the weather forecasting has been carried on from the ground. The new attack would get the weather data not only at the ground level but at altitudes up to several thousand feet above the earth's surface. Airplanes are now in use daily at many points in the United States, securing weather data above the earth. When these data are put together and studied, they reveal a much more complete picture of the conditions and movements of the air masses which surround the earth.

International News Photos, Inc.

FIG. 78. WEATHER INSTRUMENT ON AN AIRPLANE

Our atmosphere is more than twenty miles in depth, and the forces which control its movements can best be understood by seeing it not only near its bottom but also at all depths. Thus when a great mass of cold air from the arctic or antarctic regions moves in toward the warmer tropic regions, its movement can be plotted more accurately if it has been explored at all depths rather than observed only from the ground level.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 13
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 9
Hunter and Whitman, *Science in Our World of Progress,* pp. 70-75
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 10
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 3
Powers, Neuner, and Bruner, *This Changing World,* Unit 2
Skilling, *Tours through the World of Science,* Tour 3
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 6
Watkins and Bedell, *General Science for Today,* Chap. 3
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 7 (part)
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It,* Unit 2

Special references

Barber, *First Course in General Science*
Jameson, *Practical Hints for Amateur Weather Forecasters*
Jameson, *The Thermometer and Its Family Tree*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Something of the weather lore and signs of your community.
2. How to read thermometers and how they are used in foretelling weather.
3. The use of barometers in foretelling weather.
4. How relative humidity is measured and its importance in weather forecasting.
5. How the weather map is read and used.
6. How to foretell weather in an elementary way by use of the knowledge gained from this study.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The principle upon which the thermometer is based is (repulsion, expansion) ____.
2. On the Fahrenheit temperature scale there are ____ degrees between the freezing and boiling points of water.
3. On the centigrade scale water boils at ____ degrees and freezes at ____ degrees.
4. Explain the value of the thermometer in forecasting weather.
5. Forecast the probable weather for the following conditions, giving reasons in each case.
   a. A suddenly falling barometer with a wind blowing from the northeast.
   b. A sudden rise in the barometer with the wind blowing from the northwest.
   c. A steadily rising barometer with a southwest wind.
   d. A steadily falling barometer with a southeast wind.
6. By means of a drawing show how the winds blow about low- and high-pressure areas. Use arrows to indicate direction.
7. Of what value is the measurement of relative humidity in forecasting weather?
8. If the wind of a storm shifts from east through north to northwest, the center of a "low" passes (south, north) ____ of the observer.
9. If a wind from the east dies down and then springs up from the west, the "low" has passed ____ the observer.
10. If the wind of a storm shifts from the east through south to southwest, the center of the "low" has passed (north, south) ____ of the observer.
11. Establish a cause for the shift of winds as a low-pressure area passes a certain point of observation.
12. On certain days winds blow with great force. What prediction could one make concerning temperature differences and pressure differences in adjacent air masses on the basis of this observation?
13. A shaded area on a weather map means ____.
14. How is an area in which snow is falling marked on a weather map?
15. Show the sign by which a partly cloudy area is marked on a weather map.
16. What does the letter "M" marked on a weather map indicate?

TOPIC 5. INTERESTING WEATHER HAPPENINGS AND THEIR CAUSES

SUGGESTED PROBLEMS AND QUESTIONS

1. **What paths do storm areas take across North America?**
2. **What causes thunderstorms?**
3. **What is a tornado?**
4. **What is a hurricane?**

SUGGESTIONS AND HELPS FOR STUDY

1. The answers to the following questions will be found helpful in solving the problems.

a. Problem 2

What type of cloud usually develops into a storm?

How do the winds behave in the approach and passing of a thunderstorm?

In what section of a low-pressure area do thunderstorms most frequently occur?

b. Problem 3

From what type of cloud does the tornado usually form?

What gives it the rapid whirling motion which it possesses?

What is the difference between a tornado and a cyclone?

How widespread is the average tornado?

What is the size of the funnel cloud at its bottom?

Why do buildings appear to explode outwards during a tornado?

c. Problem 4

Where do hurricanes usually form?

How do they differ from tornadoes?

2. You may find the following new words and phrases in this study:

centrifugal force—force which tends to cause parts of a rotating body or system to fly away from the center of rotation.

rotate—to spin.

spiral—curl-shaped or shaped like a coil spring.

tornado—a whirling wind of great violence.

3. If possible during this study find pictures and written accounts of tornadoes and hurricanes.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What paths do storm areas take across North America? When a low-pressure area originates over the north Pacific its usual path is across the country, touching the states of the United States bordering on Canada. Storms which originate off the California coast nearly always follow a path across the southwest, either veering to the north and passing up the St. Lawrence Valley or passing into the Atlantic over Georgia and Florida.

Sometimes a storm or low-pressure area over the midwest shows a great difference of pressure from a "high" lying far to the northwest in Canada. When this occurs in fall or winter, conditions are right for cold northerly winds to set in, blowing much chilled air from the north region into the low-pressure area to the south and causing what we commonly speak of as a *cold wave.* The general eastward movement of the "low" will then spread this cold air as it travels toward the Atlantic seaboard. In this way freezing weather is sometimes carried as far south as Florida, which ordinarily enjoys a warm climate.

Heat waves in late spring, summer, and early autumn are caused by a delay in the movement of low- and high-pressure areas across the country when continued warm winds blow from the south to the front of the stagnated "low." These gather heat from the radiation of the earth as they blow northward. In this way great quantities of hot air are spread over wide areas, and the country blisters in a heat wave.

What causes thunderstorms? During the warm days of late spring, summer, and early autumn the air just above the earth becomes heated through the early part of the day much more than the air at higher levels. Some of this air begins to rise and filter through the heavier layers above. As the air rises it expands and cools, and if the cooling continues long enough, the dew point will be reached. This will cause the formation of the bottom of a cloud at this level, and as the rising current continues, a very tall cloud with a broad base will be formed. The bottom of this cloud will be dark while its top will be a fluffy white. This is the beginning of a thunderstorm.

Such a local cloud may be moving in any direction but will usually move from west to east with the prevailing winds, at a velocity of twenty to fifty miles an hour. As the storm travels, the higher portions move more rapidly than the lower parts, and hence the first appearance of a storm is a fringe of very high clouds with darker portions below.

As the storm comes on, the air becomes warm and oppressive. Wind squalls are observed and develop into a breeze which blows directly into the low-pressure center of the storm. As the center reaches an observer the wind suddenly shifts because of the inrushing currents of colder air, and rain begins to fall from the lower part of the cloud. Following the passage of the storm the barometer usually rises and the temperature falls.

Such storms may be local or may travel for distances up to six hundred miles. They travel somewhat more rapidly than the general pressure area of which they are a part. If the rising air currents of a storm are very strong they may carry the condensed water drops to high altitudes. There the temperature may be cool enough to freeze them into pellets which fall as hail.

What is a tornado? One of the most destructive storms known to man is the tornado, which occurs many times each year during the summer and early fall over the states of the Central West. While the tornado is not such a widespread storm as the thunderstorm, it is much more violent and sometimes results in loss of life and much damage to property. Figure 79 gives three photographs of an on-coming tornado.

The most striking point of the tornado is the funnel cloud which reaches the earth from a mass of low-lying black clouds above it. The funnel cloud moves along a path usually from southwest to northeast with a velocity ranging from thirty to sixty miles an hour. This cloud is made up of a rapidly rising current of warm air having a swirling motion which may attain a velocity of several hundred miles per hour. This has a tendency greatly to reduce the atmospheric pressure near the funnel cloud and to cause buildings which have normal pressure on the inside to push their walls outward toward the lesser pressure.

What is a hurricane? In recent years the state of Florida has been visited several times by West Indian hurricanes which have developed over the Caribbean Sea and gradually increased in intensity as they were carried by the winds until, after moving along the coast of Florida, they passed over the north Atlantic toward Europe.

The hurricane differs from the tornado chiefly in that it is a much larger mass of whirling air and generally moves more slowly and over a greater distance. Great walls of water are built up as the hurricane moves along over an ocean or gulf. These travel more rapidly than the storm and reach coast cities several hours ahead of the storm proper, sometimes resulting in much damage.

The U. S. Weather Bureau performs a great service when these storms develop, as it issues storm warnings to shippers, vessels, and cities on the coast. From the data which it collects it is able to foretell the path of the storm and predict when it will reach a certain point, thus allowing cities to prepare and protect themselves as much as is possible. In a recent storm one of the larger Florida cities had its relief work thoroughly organized several hours before the storm broke.

Hurricane-like storms which occur over the Pacific and Indian oceans are called typhoons.

Courtesy Taylor Instrument Company

FIG. 79. THREE VIEWS OF A TORNADO

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 13
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 9
Hunter and Whitman, *Science in Our World of Progress,* pp. 65-69
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 10
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 3
Powers, Neuner, and Bruner, *This Changing World,* Unit 2
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Webb and Beauchamp, *Science by Observation and Experiment,* Unit 7 (part)
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It,* Unit 2

Special references

Barber, *First Course in General Science*
Brooks, *Why the Weather?*
Meister, *Water and Air*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of the cause of local storms and thunderstorms.
2. An understanding of the cause of tornadoes and something of their nature.
3. Something of the hurricane and its causes.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. From which cloud types do storms most frequently come?
2. Thunderstorms most frequently form in the (west, east) ____ portion of a low-pressure area.
3. A waterspout is a (tornado, hurricane) ____ formed over water.
4. Explain the difference between a hurricane and a tornado.
5. Explain the common misconception of cyclone.
6. Houses and other buildings appear to explode and the walls fall outward in a tornado because the ____ on the outside is greatly ____ by the passing of the funnel cloud.
7. "Centrifugal" means ____

8. One often hears the statement that "dew falls." Is this a correct statement? Explain.

9. Why is it wrong to say that snow is frozen raindrops?

10. Many people believe that frost is frozen dew. Explain what is incorrect in this belief.

11. Often on cool mornings moisture on the grass is in such a form that it resembles spider webs. Some people believe that this is an indication of rain. What do you believe the cause of this phenomenon is? Is there any reason to believe that these formations might be an indication of rain?

TOPIC 6. THE CLIMATES OF THE WORLD

SUGGESTED PROBLEMS AND QUESTIONS

1. **What are the various types of climate in the world?**
2. **What are the important factors which determine climate?**
3. **How does climate affect the life that exists in it?**

SUGGESTIONS AND HELPS FOR STUDY

1. The answers to the following questions will be found helpful in solving the problems.

a. Problem 1

What type of climate has Denver, Colorado?

How would you characterize the climate of California?

What is the climate of the Sahara Desert region?

What is the climate of Alaska?

What is the climate of the Great Lakes region?

How would you characterize the climate of the Malay Peninsula?

What is the climate of Arizona and New Mexico?

What is the climate of the British Isles?

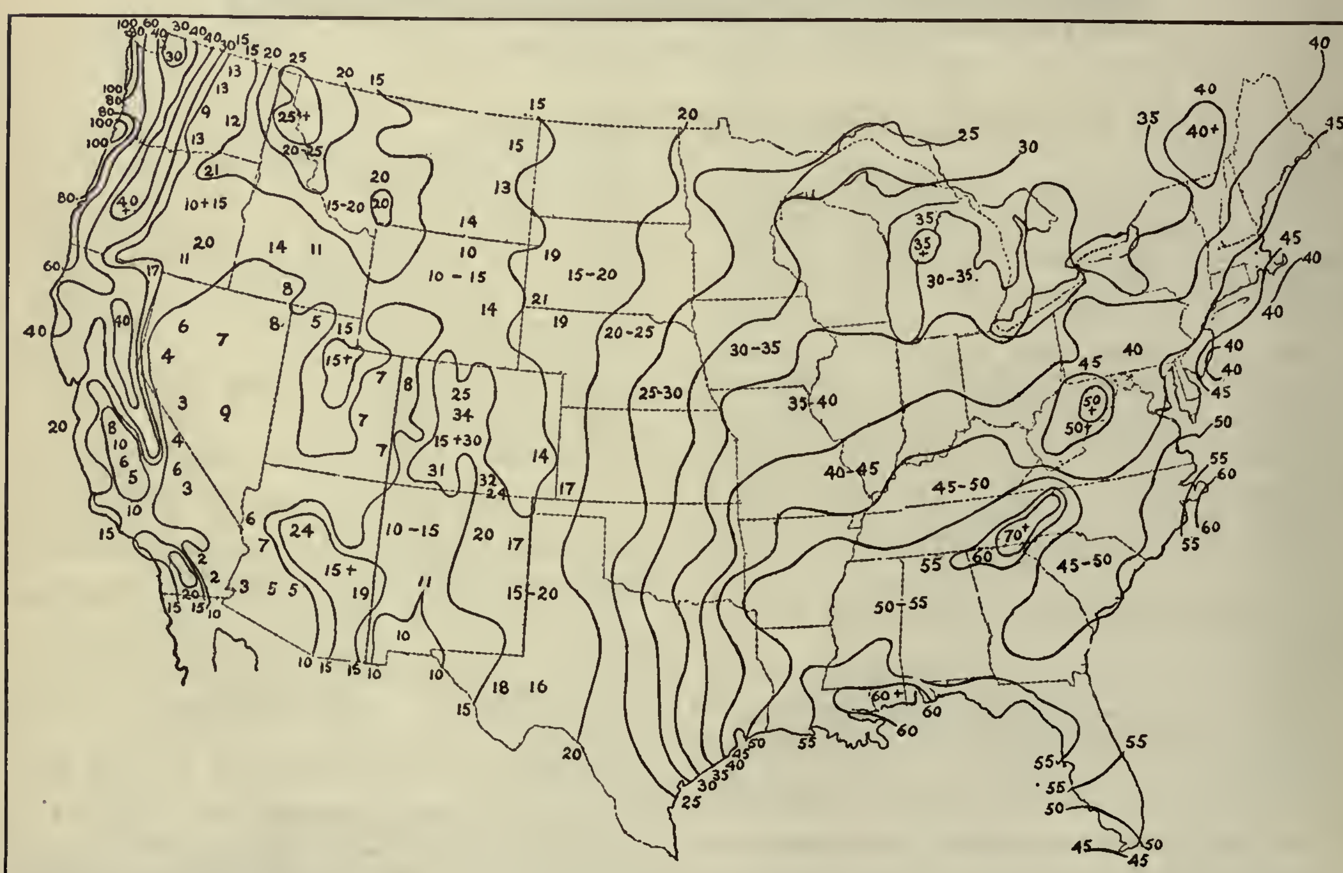
b. Problem 2

In each of the questions stated under Problem 1, what factor or factors determine the peculiar climate of that place?

c. Problem 3

How do the living things of Alaska differ from those of Central Africa?

How does climate influence one's dress?



Courtesy U. S. Weather Bureau

FIG. 80. AVERAGE ANNUAL RAINFALL IN THE UNITED STATES

How many ways does climate determine the games one plays?

How many examples can you find of the way in which climate influences what you eat?

How does climate affect the care of food?

2. Pictures of various climatic conditions and their effect on life may be made into an interesting scrapbook during this study.

3. You may find the following new words and phrases in this study:

altitude—the height of a certain region above sea level.

climate—the average weather conditions for a given area over a long period of time.

latitude—distance north or south of the equator.

torrid zone—the portion of the earth's surface on both sides of the equator and bounded by the Tropics of Cancer and Capricorn.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 33. How does rainfall influence climate?

Carefully study the rainfall map shown in Figure 80. The average annual rainfall is given in inches for the various parts of the United States. After studying the map, answer the following questions in your notebook.[1] The map does not answer all the questions.

a. What portion of the country has the greatest average rainfall?

b. How does rainfall affect the climate of that area?

c. How does rainfall affect the industry of that area?

d. What part of the country has the lowest average rainfall?

c. How does rainfall affect the climate of that area?

f. How does rainfall affect the industry and life of that area?

g. How do you account for the high average rainfall of the Pacific Coast states and the lower average for the Rocky Mountain states?

h. Determine what the average rainfall is in your locality. Do the agricultural industries of your locality depend upon the rainfall? Do they differ from those of other areas because of differences in rainfall? Explain.

Experiment 34. What are the causes of the unequal heating of the air?

Secure two small Crisco cans or others of the same type. Remove the paper from them. Blacken one of the cans all over, either with black paint or by holding it in the flame of a candle. Fill each can with water, take the temperature of each, and then place the cans in direct sunlight for a half or three-quarters of an hour. Again take the temperature of the water in each can and record. Remove the cans from the sunlight, allow them to stand for a half or three-quarters of an hour, and again measure the temperature of the water in each. Record your results in your notebook[2] and complete the following statement.

Bright shiny surfaces take on heat ____ than dark, rough surfaces.

[1] See workbook, p. 20.

[2] See workbook, p. 21.

Experiment 35. How does the angle of the sun's rays affect the heating of the earth?

Devise an experiment to study this problem.

Suggestion: Use an electric heater as a source of heat energy.

FIG. 81

Experiment 36. How do bodies of water affect the climate of the region surrounding them?

Take two water glasses and fill one two-thirds full of dark, dry earth. Fill the other two-thirds full of water and take the temperature of each. Record the temperatures in your notebook.[3]

Set each glass in the direct sunlight for a period of a half hour or forty minutes. Again take the temperature and record. Allow the glasses to stand away from the sun for a half hour and record their temperatures a third time.

Complete the following statement and write the required explanation in your notebook.

The water heats ____ than the soil. The water cools more ____ than the soil. Explain how this would affect the climate of such a locality as the Great Lakes Region.

Activity 37. What effect does altitude have upon climate?

Compare the climate of Denver, Colorado, or some other mountain city with that of a city in the same latitude but having a lower altitude. In what ways does altitude affect climate?

International News Photos, Inc.

FIG. 82. A DUST STORM ON THE SAHARA

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What are the various types of climate in the world? It is not uncommon to hear an older person remark that winters are not so cold as when he was young or that the summers are not now so hot. Such statements have been carefully checked against the records of the Weather Bureau and usually found to be false. The

[3] See workbook, p. 22.

general climate of a region averages about the same year after year and changes only slightly over long periods.

It is perfectly natural that people should think that climate changes frequently, for we are continually experiencing changes in the weather from hour to hour and day to day. Temperature changes, winds change, pressure changes, and relative humidity changes, and yet when each of these factors is averaged, year after year, about the same result for a given locality is obtained. This average of all the weather conditions is spoken of as the climate of that region.

There are many types of climate on the earth. The polar regions, both Arctic and Antarctic, are ice-bound wastes where the temperature stays most of the time below the freezing point of water. There is a band about 1500 miles wide on either side of the equator encircling the globe where one may encounter the highest temperatures, luxuriant growth, freezing temperatures and no growth, the most arid parts of the world, and the regions of greatest moisture or relative humidity. This is due principally to variations in rainfall and altitude. England is farther north than New York, and yet its climate is much milder. The climate of regions near bodies of water is much more moderate than regions in the same latitude but away from water. A city that has a high altitude may experience a much different climate from that of one nearby but at a lower altitude. Study the pictures of this topic and learn all you can from them about the varied climates of the world.

International News Photos, Inc.

FIG. 83. THE CLIMATE OF THE POLAR REGIONS

The earth is divided into climatic zones. Figure 84 shows these zones and their boundaries. The Torrid Zone is the largest, extending 23½ degrees on either side of the equator. In the Northern Hemisphere the Torrid Zone is separated from the North Temperate Zone by an imaginary line known as the Tropic of Cancer and in the Southern Hemisphere from the South Temperate Zone by a similar line, the Tropic of Capricorn. The North and South Temperate Zones are 43 degrees in width. The North Temperate Zone extends from the Tropic of Cancer to the Arctic Circle and the South Temperate Zone from the Tropic of Capricorn to the Antarctic Circle. The North Frigid or Arctic Zone lies between the Arctic Circle and the North Pole, while the South Frigid, or Antarctic Zone is between the Antarctic Circle and the South Pole. Each of the two frigid zones extends 23½ degrees from the pole.

The boundaries of the zones of the earth are established by astronomy. The boundaries are based upon the following facts: that the earth is inclined on its axis 23½ degrees to the plane of its orbit, that it rotates on its axis, and that it revolves about the sun. When the earth is in such a position in its orbit that the North Pole is toward the sun, the sun's rays just cover the North Frigid Zone. In other words, they extend as far as the Arctic Circle. This occurs about June 21 of each year. Six months later when the earth has moved half way around its orbit, or about December 21, the South Pole is toward the sun and the rays extend 23½ degrees from this pole, or as far as the Antarctic Circle. In other words, they cover the South Frigid Zone.

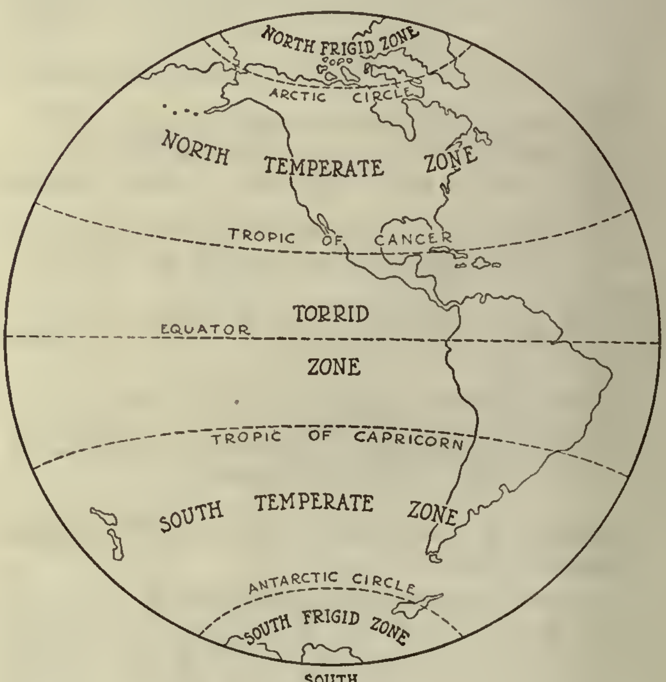


FIG. 84. CLIMATIC ZONES

The Tropics of Cancer and Capricorn represent the farthest points north and south of the equator that the vertical rays of the sun strike.

While the boundaries between the zones are established exactly by astronomy, they are of little importance as exact climatic boundaries. For example, there is no marked change of such climatic factors as temperature and rainfall as one crosses from the Torrid Zone over the Tropic of Cancer into the North Temperature Zone.

Some interesting seasonal variations occur in the various zones. In the Torrid Zone the days and nights are of about equal length the year around, there are no winters, and cold weather is practically unknown except at very high altitudes.

In the temperate zones the days and nights are of equal length only twice during the year, about March 21 and September 21. In summer the days are longer and the nights are shorter, while in winter the conditions are reversed. The northern hemisphere has summer while the southern hemisphere has winter and vice versa. How strange it would seem to have skating and coasting in July and August or to have Christmas under a warm sun.

In the frigid zones we find a still stranger situation. During the part of the year when the north pole is toward the sun, the Arctic Zone has continuous day, while the Antarctic Zone has continuous night. Six months later the conditions are just reversed. In Alaska it is not unusual in the summer to play a game of ball in broad daylight as late as eleven o'clock in the evening.

Underwood and Underwood

FIG. 85. IN THE TROPICAL JUNGLES OF BORNEO

What are the important factors which determine climate? The variations of climate in different parts of the world as shown by the pictures of this topic would lead one to believe that there might be several causes of climatic conditions. This is true, for climate may be influenced by the amount of sunshine and darkness, temperature, humidity and rainfall, altitude, latitude, nearness to bodies of water, and the prevailing winds.

Sunshine is probably the most important of all of the factors determining climate, inasmuch as so many of the others owe their effect to it. Temperature is a direct result of the amount of sunshine received by a given region. Humidity is affected by sunshine and winds, and bodies of water owe their effects on climate to sunshine. It has been said that during the period between the first of June and the fifteenth of July, the region around the North Pole receives more heat than an equal area anywhere else on earth. From this it would seem that gradually this region should grow warmer and warmer and the ice and snow melt back, but we know that this does not happen to a great degree. The reason, of course, is that a large portion of the heat received is used in melting the ice and snow and not in warming the water; then during the next winter more ice and snow will form, for during six months of the year the sun does not shine on the polar regions.

Underwood and Underwood

FIG. 86. A SCENE IN THE CORN BELT OF THE UNITED STATES

The climate of a particular region of the earth is, in part, determined by the amount of heat energy which it receives from the sun. A region which for some reason has greater cloudiness and less sunshine will have a lower average temperature than a region which receives more sunshine, other factors being equal. One naturally asks then why the polar regions which receive nearly six months of sunshine each year are not tropical and warm rather than barren wastes of ice and snow swept by fierce, cold winds.

It is true that summer in the polar regions is much warmer than winter. There are, however, two other factors of great importance regarding the heat energy of the sun which are largely the causes of the cold climate about the poles of the earth. As you have already learned, the winters in the polar regions are also nearly six months in length. During this period much ice and snow accumulates. When summer comes much of the sun's heat is used in melting this ice

and snow and thus does not warm the land, water, and air. Moreover, the sun's rays which strike the polar regions are very slanting. Hence the energy is spread over a much larger area, and less heat is received on any single unit area. In the tropical regions, on the other hand, wherc the sun's rays are more direct, the same amount of energy is concentrated on a smaller area. This is clearly shown by Figure 87.

Nearness to bodies of water influences the climate of a given region. Your experiment has taught you

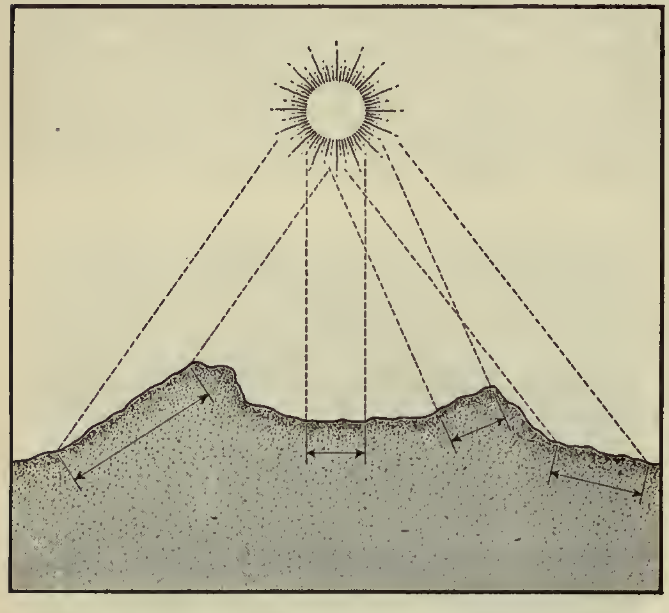


FIG. 87. DIRECT AND SLANTING SUN RAYS

The slanting rays from the sun cover more space, and, therefore, each unit area receives less heat than a similar area under direct rays.

that water heats more slowly and gives out its heat more slowly than the land surrounding it. This has a tendency to moderate the climate near bodies of water, that is, to make the summers cooler and the winters somewhat warmer. Can you explain why this would follow from what you have learned? Ncarness to large bodies of water often determines a fruit growing region, as the slow warming of the water tends to retard the plant development in early spring when frosts might harm the buds or blossoms and also its slow cooling makes for a long fall, holding off the frosts and providing ample opportunity for ripening. Do you know of an area near a lake which is a fruit region?

A study of the rainfall chart, Figure 80, will show you some ways in which rainfall influences climate. Turn to the chart and compare the rainfall of California with that of Maryland. How do they differ? How does this condition influence the climate in each of these sections? Have you ever been in a greenhouse and noticed the large amount of moisture in the air? High relative humidity is a factor which tends to make luxuriant plant growth. The tropical regions in general have high relative humidities, and it is in these regions that we find the jungles of Asia and Africa, where the plant growth is so luxuriant that it can hardly be penetrated by man.

The climates of places at different elevations above sea level vary, largely because of the decrease in the weight of air, volume for volume. Two cities may be in the same latitude, each near or away from water, and yet have different climates because of differences in their altiudes. Denver, Colorado, and Columbus, Ohio, are two such cities. Can you suggest ways in which the climates of these two cities would vary?

Ocean currents influence the climate of certain regions. The western shores of Europe and of North America are relatively mild as far as climate is concerned. Roses bloom in midwinter in the states of Washington and Oregon, and even in Alaska the winters are no more severe, in certain parts, than in the States. The climate of England is much milder than that of Labrador in North America, although both are situated in about the same latitude. What is the cause of these seeming peculiarities in climate? In general, they are due to ocean currents.

The warm water of the tropics tends to flow outward toward the poles. If the earth did not rotate on its axis, these currents would flow nearly north and south, but instead they are deflected northeastward in the northern hemisphere and southeastward in the southern hemisphere. The principal currents of the Atlantic Ocean are the Gulf Stream and the Labrador Current. The Japan Current is the most important one of the Pacific Ocean. There are also currents in the Indian Ocean.

The Gulf Stream flows out of the Gulf of Mexico carrying its warm waters north and east until it strikes the British Islands and then northward to the coast of north Europe. These warm waters greatly moderate the climate of west and north Europe. In a similar manner the Japan Current carries warm waters north and east until they strike the shores of Alaska and are deflected southward to moderate the climate of the entire west coast of North America.

How does climate affect the life that exists in it? Figures 82-86 illustrate this fact. In desert regions the cacti and other desert plants develop leaf exposures modified to lose as little water as possible. In tropical climates there is a rank, luxuriant growth of foliage brought about by the high humidity and torrid heat.

The determining of plant and animal life is clearly seen in the various climatic areas of the United States. Cotton, which needs a warm climate, is raised in the south. Iowa and Illinois are the corn states, and here

also we find the center of the hog-raising industry. The even rainfall of the northern and eastern sections of the country accounts for good grass and grain crops and a large part of the dairy industry of the country. Near the lake and coastal regions we find much of the fruit industry centered because of the moderating effect of water on the climate of these regions.

Climatic conditions determine the progress of civilization. Extremes of climatic factors do not make for progress in civilization, and areas which experience frequent changes of temperature, pressure, sunshine, and humidity are the places where human energy is at its highest. Tropical regions with their extreme heat, high humidity, and resultant dense growth provide difficult living conditions and tend to retard progress. The extreme low temperatures of the Arctic and Antarctic regions make life there very difficult, and as a result civilization in these regions has never progressed far, as evidenced by the primitive type of life led by the Eskimo. On the other hand, we find that civilizations have made the greatest progress in general when they have been located in more temperate climates or where changes are experienced more frequently.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 13
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 9
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 9
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 3
Powers, Neuner, and Bruner, *This Changing World,* Unit 2
Skilling, *Tours through the World of Science,* Tour 3
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 6
Watkins and Bedell, *General Science for Today,* Chap. 3
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 7 (part)
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It,* Unit 2

Special references

Carpenter, *Geographical Readers*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the various types of climates of the world.

2. The causes of unequal heating of the air and how this affects climate.

3. How rainfall affects climate.

4. How nearness to bodies of water affects the climate of a region.

5. How altitude affects climate.

6. How ocean currents influence the climate of certain areas.

7. How the climate of a given region determines its plant and animal life.

TEST OF MASTERY OF THE TOPIC

In your notebook answer the questions and comply with the instructions.

1. Give reasons for the unequal heating of the atmosphere.

2. What is the average rainfall of your region?

3. How are the climates of the eastern and western slopes of the Rocky Mountains determined by the prevailing winds of that region?

4. Why does a large body of water moderate the climate of the surrounding region?

5. Why is the climate of England milder than that of the eastern United States, even though it is considerably farther north?

6. List some of the different types of climate found on the the earth. Give an example of each.

7. In what way does altitude affect climate? Give an example.

8. Show how moving from a tropical city to some place in Alaska would affect one's mode of living.

9. Does climate affect the progress of mankind? Explain.

10. How is relative humidity a determining factor of climate?

11. It has been said that during the 45 days from May 31 to July 16, the region about the North Pole actually receives more heat than does an equal area anywhere else on earth. Explain why, then, the north polar regions do not become gradually warmer.

12. How does the length of day and night affect the sun's heating power and therefore the climate of a given region?

13. The ____ divides the Tropic Zone from the South Temperate Zone.

14. The Tropic of Capricorn lies between ____ and ____.

15. Explain the difference in heating power of the slanting and direct rays of the sun.

16. How much is the axis of the earth inclined to the plane of its orbit?

17. From your study of this topic predict the probable conditions in the arctic region on September 21 concerning the following: relative lengths of day and night, relative temperature.

18. Establish a possible cause for ocean currents.

SUPPLEMENTARY MATERIALS

Reading suggestions

Brooks, *Why the Weather?* (Harcourt)
Archibald, *The Story of the Earth's Atmosphere* (Appleton)
Bond, *The American Boys' Engineering Book* (Lippincott)
Longstreth, *Reading the Weather* (Macmillan)
Rolt-Wheeler, *The Boy with the U. S. Weather Men* (Lothrop)
Fisk, *Exploring the Upper Atmosphere* (Oxford)
Harrison, *Daylight, Twilight, Darkness, and Time* (Silver)

Van Cleef, *Story of the Weather* (Century)
Heile, *The World's Moods* (Follett)
Free and Hoke, *Weather* (McBride)
Elm, *Weather and Why* (McKay)
Luckiesh, *The Book of the Sky* (Dutton)
McAdie, *Fog* (Macmillan)
United States Weather Bureau Bulletins
The Daily Weather Map with Explanations
Explanation of the Weather Maps
The Weather Bureau
Weather Forecasting, No. 42
Wind Barometer Table

Reports which may be prepared

1. The early history of the thermometer
2. Cloud formations and their use in weather forecasting
3. The weather prediction service of other countries
4. Weather instruments and their uses
5. Interesting weather lore
6. Thunderstorms and their causes
7. The tornado
8. Historic hurricanes
9. The various forms of water
10. Interesting temperatures and their measurement
11. How the weather map serves the people of the country
12. Aviation and the weather
13. A visit to the local Weather Bureau
14. Observations made during a thunderstorm
15. Storm warnings used by the United States Weather Bureau
16. The good and bad features of the climate in which I live

Great scientists you should know about

1. Gabriel Fahrenheit
2. Benjamin Franklin
3. Galileo Galilei
4. Otto von Guericke
5. Blaise Pascal
6. Evangelista Torricelli

Investigations and things to do

1. Make a set of weather flags.
2. Make a rain gauge.
3. Make a weather map for a series of days.
4. Make a device for telling the velocity of the wind.
5. Make a thermometer. See Good, *Laboratory Projects in Physics.*
6. Make a sling psychrometer for measuring relative humidity.
7. Visit the local Weather Bureau station.
8. Set up an amateur weather forecasting station.
9. Make a scrapbook of clippings and articles about the weather.
10. Make a hygrometer from two cheap thermometers.

UNIT III. THE RELATION OF THE WATER SUPPLY TO THE WELFARE OF THE COMMUNITY

There are three necessities without which man cannot exist: air, food, and water. The last of these, water, because it is such a common thing, is often not appreciated. We are so accustomed to going to a well or a faucet for water whenever we are thirsty or wish to take a bath that we seldom stop to consider how not only our comfort but our very life is directly dependent upon it. Without water all plants and animals would die and our earth would soon be a barren place.

Water is important to us personally. Since the human body is more than 65 per cent water, we must drink large quantities in order to live. Water carries dissolved foods in the body and is necessary for the removal of waste matter. Large quantities of water are also used in our homes and communities to keep them clean. These services are of inestimable value in adding to our health and happiness.

Think of the tremendous importance of water to our industries. Large quantities of it are needed in boilers to form steam. It is the best and cheapest solvent[1] for many purposes. It is also a source of much power. More and more streams and falls in this country are being harnessed to furnish the energy to generate electricity.

There are many other ways in which we use water. Perhaps you will find it interesting to make a list of all the ways you can find in which man makes use of water. In this unit you will learn many new and interesting things about water. You will learn what it is, how it is purified, what the dangerous impurities in it are, and how it is controlled and distributed to our homes.

[1] *Solvent*, a substance which dissolves other substances.

What do you already know about water? Write the answers in your notebook under the proper heading.

1. How long can you live without water?
2. Why must living things have water?
3. What is the source of the drinking water in your home? How is it kept clean and pure?
4. Is ice a form of water? Is snow water? What is water?
5. How can water in the home be made safe for drinking purposes?
6. How do large cities keep their water supply clean and pure?
7. What is hard water? Soft water?
8. Are the streams in your community being polluted[2]? If so, what are the principal sources of the pollution?
9. What are the dangers to a community of improper methods of sewage disposal?
10. Where does the water in wells come from?
11. Have you any leaky faucets in your home? How do you repair a faucet?

[2] *Polluted*, made impure.

TOPIC 1. METHODS OF PURIFYING WATER

SUGGESTED PROBLEMS AND QUESTIONS

1. What is water?
2. What impurities are commonly found in water?
3. How are chemical impurities removed from water?
4. How is water purified in the home?
5. How is water purified by distillation?
6. How are temporary and permanent hardness removed from water?

SUGGESTIONS AND HELPS FOR STUDY

1. The safeguarding of the water supply is an important problem for every home and every community and often a difficult one. Study the problems carefully in order to learn what impurities may be found in water. The study of this topic will teach you how they may be removed.

2. You may be able to carry out, on a small scale, some of the methods used to purify water. Read the experiments suggested in the next section.

3. Study the following words and see if they are new or difficult for you.

sterilize—to free from disease germs.

disinfectant—a substance which purifies by killing disease germs.

bacteria—tiny one-celled plants.

soluble—capable of being dissolved.

solution—a substance in which some other substance is dissolved or the mixture resulting when a substance is dissolved in another.

hard water—water which contains dissolved substances.

insoluble—not capable of being dissolved.

solvent—a liquid in which other substances can be dissolved.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 38. How can hardness of water be removed?

Obtain some water from a faucet in your home or school house or from a well in your neighborhood. Shake soap in the water. Do suds appear soon? If so, it is soft water. Soft water has very little mineral matter dissolved in it.

If suds do not appear soon the water is hard. If the water is hard, boil some of it. Shake soap in it again. Do suds appear soon? If so, the water possesses only *temporary hardness,* which is removed by boiling.

If suds do not now appear at once, the water possesses *permanent hardness.* Add some borax or washing soda to the water. Add soap and shake. Do suds appear at once? Permanent hardness must be removed by the addition of chemicals to the water.

In your notebook[1] record the notes of this experiment and answer the following questions.

What do the terms hard and soft water mean? How is temporary hardness of water removed? How is permanent hardness of water removed? Where do the substances that make water hard come from?

Experiment 39. How is water purified by filtration?

FIG. 88. HOW A FILTER WORKS

Tie a piece of cloth over the top of a lamp chimney and place it over a glass vessel (see Figure 88). Pour coarse sand into the chimney until it is about half full. Next pour fine sand into the chimney until it is about an inch and a half from the top. Prepare some muddy water and pour it into the top of the chimney.

Record the notes and results of this experiment in your notebook.[2]

Experiment 40. How do certain chemicals help to purify the water?

Fill a tall bottle with muddy water. Put a small amount of alum in it. Allow it to stand for a day and note the change that has taken place. Do you know of any other chemicals besides alum that are used to purify water?

Record the notes and results in your notebook.[3]

Experiment 41. How is water purified by distillation?

Set up apparatus similar to that shown in Figure 89. Draw some water from the faucet and add some dirt, sugar, and salt to it. Put it into the flask and boil for awhile.

Examine the distilled water which collects in the test tube. Does it have any color? Any odor? Any taste?

In your notebook[4] record the results of this experiment, complete the following statements, and answer the questions.

1. When water is distilled it is first ____ and then ____.
2. The impurities in the water remain ____.
3. What are some of the uses of distilled water?

[1] See workbook, p. 23.
[2] See workbook, p. 23.
[3] See workbook, p. 23.
[4] See workbook, p. 24.

Experiment 42. What is the composition of water?

Set up apparatus similar to that in Figure 90 or use a Hoffman's electrolysis outfit if you have one. *Add cautiously a little strong sulphuric acid solution to the water before putting it into the apparatus (about 5 cubic centimeters).* Use about four dry cells connected in a series (carbon of one cell connected to the zinc of another). Connect the wire marked *a* in the diagram to the carbon of the first cell and the wire marked *b* to the zinc of the last cell. Notice the bubbles of gas appearing on the small pieces of platinum. Notice later the amount of gas collected in each tube.

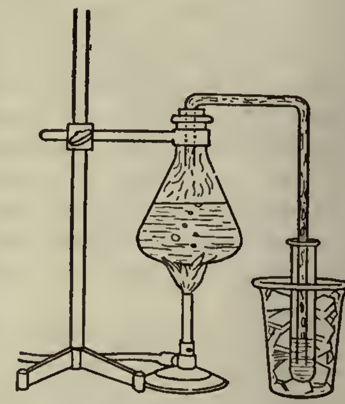


FIG. 89. HOW WATER IS DISTILLED

When the tubes are partly filled with gas, remove them by means of a glass plate and set them upright. Using a ruler, measure the amount of gas in each jar. Hydrogen will explode with a pop when a flame is brought near it, while oxygen will make the flame burn more brightly. Test the gas in each jar.

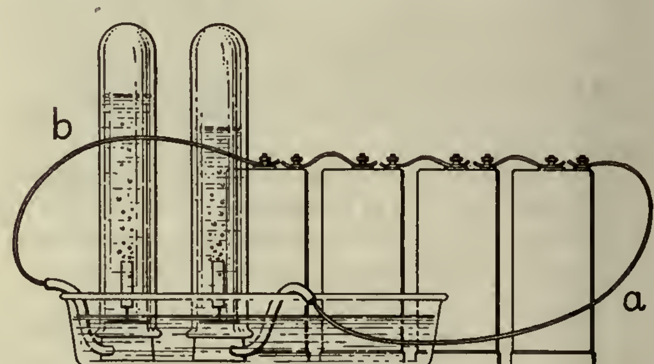


FIG. 90

In your notebook[5] record the notes of this experiment and complete the following statements.

In each case the gases were ____ in color. One gas collected about ____ as fast as the other. This gas by test was proved to be ____. From these observations one may infer that water is composed of the two substances ____ and ____ in the proportion of ____ parts of ____ to ____ part of ____.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is water? We see it in our lakes, streams, and oceans; in fact, about three-fourths of the earth's surface is covered with water. We pump it from wells or see it flow from our hydrants. We know it exists under the surface of the earth, and we see it in the atmosphere in the form of clouds, rain, or snow.

In spite of our familiarity with water many of us do not know what it really is. Have you tried to sepa-

[5] See workbook, p. 24.

rate water into its parts by means of electricity as suggested in one of the experiments at the beginning of this topic? This experiment shows that water is a chemical compound made up of two parts of hydrogen to one part of oxygen.

water = hydrogen (two parts) + oxygen (one part)

Pure water has no odor or taste. Drinking water generally has a taste and sometimes an odor because of the presence of dissolved substances or living organisms in it. Small quantities of water are colorless, but large quantities show a distinctly blue color.

Recently another kind of water known as heavy water has been found mixed in with the molecules of ordinary water. A method of separating heavy water has been devised, but it is costly, thus making the substance expensive to buy. Heavy water is heavier than ordinary water because it contains another kind of hydrogen which is two times as heavy as ordinary hydrogen. Heavy water has some very different properties from ordinary water. Among them is the property of killing certain types of simple living organisms which live in ordinary water.

All of us know how readily many substances like sugar and salt disappear in water. We call a liquid which dissolves substances a solvent. Water is sometimes called the universal solvent, because it will dissolve a great many substances and because it is cheap and easy to obtain.

What impurities are commonly found in water? Absolutely pure water can be obtained only by artificial means. Because water dissolves many materials which occur in nature, it is practically impossible to secure an adequate supply that does not contain dissolved substances. Then, too, water carries suspended matter, and many tiny plants and animals may also be found in it.

In general, the impurities found in water may be put into three classes:

Dissolved matter. Dead plants and animal matter decay and dissolve in the water in which they are present for a long time. Water dissolves mineral substances from rocks and soils through which it passes. Also gases from the air and other sources are somewhat soluble in water.

Suspended matter. If we take some very fine sand and clay, and stir them in water, what seems to be a uniform mixture is obtained. On standing, however, most of the solid matter slowly settles out. Such mixtures are called *suspensions.* Small bits of plants, animal matter, clay, sand, and other types of sediment are carried in suspension by most streams of water.

Living organisms. Water generally contains tiny living things, many of which are so small that they cannot be seen with the unaided eye. Most of these are not harmful to the body when taken in with the water we drink. It is definitely established, however, that some diseases are spread by water containing disease-producing bacteria (tiny plants). The disease typhoid fever is often spread in this way. We cannot tell by looking at, or tasting, water whether it contains disease-producing organisms. It must be examined with the aid of a microscope and chemicals. Some cities employ bacteriologists to do this work. See Figure 129.

To be satisfactory for drinking purposes water must be free of any substances which have an injurious effect on the human body, and must possess no characteristics which make it offensive to those who drink it. To meet these requirements water should possess the following qualities: be free of poisonous chemicals and living things which produce diseases; possess no offensive taste or odor; be clear and reasonably cool; have a low content of dissolved substances.

How are impurities removed from water? Since natural supplies of water generally do not meet all of these requirements, artificial methods of purification must be used. Four methods of water purification are in use today where large quantities are needed for communities.

Chemical treatment. Water that contains disease-producing organisms is treated with some disinfecting agent. The most common chemical used for this purpose is chlorine. This gas may be applied to the water directly or in one of its chemical compounds. Bleaching powder (chloride of lime) is a white solid containing chlorine which is commonly used to purify water. The proper amount of it added to the water supply will make the water fit to drink, but it sometimes gives the water a slight taste.

Ozone (a form of oxygen) is being increasingly used to purify water, as it has several marked advantages over chlorine and chloride of lime. It is in no way injurious to the human body, adds no disagreeable taste to water, but sterilizes it and removes all taste and color due to organic matter.[1] It has the disadvantages of being more expensive than chlorine and chlorine compounds.

Chemicals may also be used to remove suspended matter from water. Certain chemical compounds of iron and aluminum when added with lime to water form a jelly-like mass which entraps suspended particles and causes them to settle to the bottom.

Sedimentation. Water that contains a large amount of suspended matter will lose much of this material if it stands undisturbed long enough. A stream is able to carry a large quantity of suspended matter which it loses by the process of sedimentation as soon as the velocity of its current is decreased. In many water-purification systems, water from natural sources is run into large sedimentation basins or settling tanks

[1] *Organic matter,* matter pertaining to living things.

where most of the sediment settles out. Then the water is further purified by other means.

Filtration. Suspended matter, and to some extent bacteria, may be removed from water by filtration. This method does not remove dissolved substances, nor does it completely take out all living organisms. Water which is carrying disease-producing organisms should be treated with some chemical like chlorine or chloride of lime in addition to being filtered.

Courtesy of St. Louis Department of Public Utility

FIG. 91. INTERIOR VIEW OF A CITY FILTRATION PLANT

City filter systems consist of beds of sand, often an acre or more in extent. The bottom of the sand bed is covered first with broken stone or large gravel. On top of this are placed successive layers of small gravel, fine gravel, coarse sand, and fine sand. The openings in the sand are so small that only water, dissolved substances, and some bacteria can pass through. Oxygen from the air penetrates the sand and kills some of the bacteria. After a time the spaces between the sand particles become clogged with dirt and bacteria. Then the filter must be cleaned and washed free of its impurities.

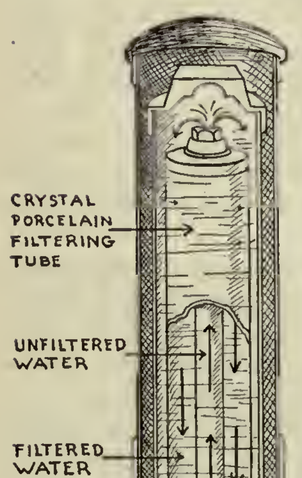


FIG. 92. A HOME WATER FILTER

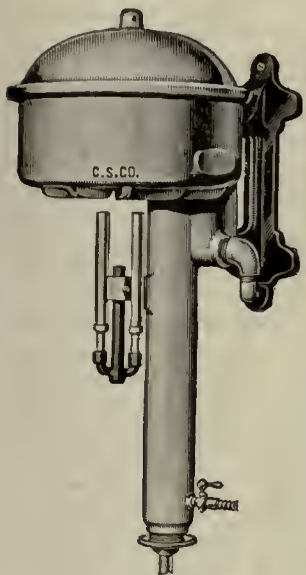
Aeration. This process of purification consists of mixing air with the impure water. It is carried on in a number of different ways, a common method being to spray the water through the air in fountains. See Figure 104. Aeration helps to remove iron and organic matter and kills some disease-producing organisms. It cannot be used alone, however, as it is not effective for some dangerous impurities.

How is water purified in the home? In the country and in smaller communities it is sometimes difficult to obtain pure water for drinking purposes. Then the water must be purified in the home. Two methods are in common use for purifying water in the home, namely, filtration and boiling. Many types of home filters are on the market today. The most common filtering materials employed in these home filters are sand, charcoal, porous stone, and powdered glass. Domestic filters are dangerous to use because they do not insure absolute purity. If disease-producing organisms are present in your water supply, all water for drinking purposes and water to be used in the preparation of foods should be boiled. Boiling will destroy all disease-producing bacteria present in impure water. Boiling is the only sure method which can be used in the home for purifying water.

How is water purified by distillation? None of the methods of purification mentioned thus far completely removes dissolved substances from water. If water free from dissolved substances is needed, it must be distilled. The process of distillation is carried out by heating water until it vaporizes (evaporates) and then condensing the steam, thus leaving behind all dissolved and suspended solids. This method is too expensive to use for purifying large quantities of water such as are needed by communities. Distillation is used in scientific laboratories to obtain pure water for experimental purposes. It is also used by the United States Navy to convert sea water into drink-

ing water. Have you performed the distillation experiment suggested at the beginning of this topic?

How are temporary and permanent hardness removed from water? Have you ever heard water spoken of as "hard" or as "soft" water? Does the water in your locality quickly and easily form lather with soap or does it lather with great difficulty?



Central Scientific Co.

FIG. 93. LABORATORY STILL

We have already learned that water is a good solvent. As water seeps through sand and rock layers of the earth it dissolves some of the substances with which it comes in contact. Thus when this water is used for home or industrial purposes it has in it some dissolved solids. Water containing dissolved substances is called *hard water.* Water without any dissolved solids in it is called *soft water.* Rain water is soft water.

Hard water generally has calcium, magnesium, or iron compounds dissolved in it. If these compounds can be removed by boiling, the water is said to possess temporary hardness. The soluble substances are changed to insoluble substances by heat, and settle out. This produces the hard crust often found in tea kettles and boilers. Do you know what boiler scale is?

Courtesy Heine Boiler Co.

FIG. 94. BOILER SCALE IN A PIPE

Dissolved solids which cannot be removed from water by boiling produce what is known as permanent hardness. Heat has no effect on the dissolved substances in permanently hard waters. Soap can be used to soften water, but it is more economical to use some cheaper substance. Washing soda (sodium carbonate or sal soda) and borax are the chemicals most commonly used for this purpose. Washing soda is six times more effective in softening water, pound for pound, than soap. Also washing soda is cheaper per unit of weight than soap.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 5

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Hunter and Whitman, *My Own Science Problems,* Unit 4

Lake, Harley, and Welton, *Exploring the World of Science,* Chaps. 6, 7

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Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 5

Watkins and Bedell, *General Science for Today,* Chap. 4

Webb and Beauchamp, *Science by Observation and Experiment,* Units 1, 3, 4 (parts)

Wood and Carpenter, *Our Environment: Its Relation to Us,* Unit 1; *Our Environment: How We Adapt Ourselves to It,* Unit 3; *Our Environment: How We Use and Control It,* Chap. 6

Special references

Garnett, *A Little Book on Water Supply*

Hessler, *Junior Science*

Prudden, *Drinking Water and Ice Supplies*

Meister, *Water and Air*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the impurities commonly found in water.
2. A knowledge of the common methods in use to purify water.
3. A knowledge of how to purify water in your own home.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Water for drinking purposes can be safely purified in the home by ____.
2. Soft water is water that does not contain ____.
3. Three different classes of impurities found in water are ____.
4. Temporary hardness can be removed from water by ____.
5. Three methods commonly employed by cities to purify water are ____.
6. The disease most commonly spread by impure water is ____.
7. Define distillation.
8. Permanent hardness of water may be removed by ____.
9. Permanent hardness of water is due to ____.
10. Some chemicals used to purify water are ____.
11. What is heavy water, where is it found, and how is it obtained?

TOPIC 2. HOW COMMUNITIES OBTAIN PURE WATER

SUGGESTED PROBLEMS AND QUESTIONS

1. How do persons who live in the country or in small towns secure an adequate water supply?
2. How are the inhabitants of large cities supplied with pure water?
3. Of what importance is pure water to the health of a community?

SUGGESTIONS AND HELPS FOR STUDY

1. The study of this topic should make it possible for you to get a general idea of how pure water is obtained by people living in several types of communities.

2. During the study of this topic you should make a detailed study of your own water supply and compare it with the methods used in other places.

3. To make it possible for you to compare your water supply with others used, this topic will deal with types of water supply such as those used in rural districts and those used in towns and cities.

4. You may find the following new words in this study:

precipitate—a solid, insoluble substance formed in a solution.
baffle—a device used to break the flow of water or turn it in another direction.
sludge—mud or mire.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 43. How do settling basins work?

Stir some mud and dirt with water and pour some of it into a tall jar or fruit can. Observe the mixture after it has stood for several hours.

In your notebook[1] answer the following questions. What happened in the jar? Was all the suspended matter affected by this process? What still remained in the water at the top of the jar? Can you suggest a means for removing this without filtering?

Experiment 44. Do chemicals aid the settling of suspended matter in water?

a. Dissolve a small amount of iron sulphate (green vitriol) in a test tube half-full of water and add a little of it to some clear limewater.[2] Allow the mixture to stand for some time. Observe what happens and record your observations in your notebook.[3]

b. Dissolve a little aluminum sulphate (alum) in a test tube half-full of water. Place some clear limewater in another test tube and add half of the aluminum sulphate solution to it. If the test tube is now warmed gently the desired action will take place more quickly. Allow the tube to stand undisturbed for some time. Record your observations in your notebook.

c. Stir some mud with water and place some of the mixture in a tall jar such as a fruit jar. Add about a quarter teacup full of limewater to this and then about the same amount of iron sulphate solution. Allow to stand for some time until the settling of the green precipitate is completed. Siphon the partly clear water from above the settled matter and place in another tall jar. To this add more limewater and some aluminum sulphate solution. Allow this to stand and settle. It may require several hours. Compare the settling in the first and second jars. Record your results in your notebook.

Now complete the following statements and write the required paragraph.

a. A solid, insoluble substance formed in a solution as a result of chemical action is called a ____.

b. The precipitate was formed as a result of the chemical action between ____ and ____.

c. The precipitate formed in part a of the experiment was ____ in color and (heavier, lighter) ____ than water.

d. The particles of the green precipitate were (larger, smaller) ____ than the particles of the white precipitate formed in part b.

e. The precipitate in part b was formed as a result of the chemical action between ____ and ____.

f. It was ____ in color and (heavier, lighter) ____ than water.

g. Its particles were (large, small) ____.

h. Write a summary paragraph showing how the two chemical actions studied above are used to aid the settling of the suspended matter in water. Why is iron sulphate used before the aluminum sulphate?

[1] See workbook, p. 25.

[2] Prepare limewater by stirring unslaked lime into a jar of water. Allow it to stand awhile and then pour off the clear limewater.

[3] See workbook, p. 25.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

There are several ways of securing water. In rural districts, in small towns, and in a few large cities, wells driven into underground streams make up the source of water supply. A lake may supply cities and towns near it. Rivers and smaller streams, however, make up the most important source of water supply for cities and towns along them. It is often the case that the location of a city determines the source of its water supply. Cities away from rivers and in desert country must resort to wells, while a city in the mountains has lakes and streams formed by melting snows for its supply.

In rural districts and in most small towns, providing water is not such a tremendous problem as it is in large cities, where water is often brought many miles through pipes to supply the need. The following table gives the average daily water consumption per person in some of the larger cities of the country.

CITY	POPULATION (1930)	GALLONS PER PERSON PER DAY
Chicago, Ill.	3,376,438	280
Philadelphia, Pa.	1,950,996	172

Cleveland, Ohio	900,429	160
St. Louis, Mo.	821,960	150
New York City	6,930,446	140
Kansas City, Mo.	399,746	132
Boston, Mass.	781,188	118
Los Angeles, Calif.	1,238,048	112

From this table it can be seen that providing the water for a large city is a real problem.

How do persons who live in the country or in small towns secure an adequate water supply? The most common method of securing water for the country home is from wells and cisterns. This method is used also in many towns and villages and in some large cities. Because water from wells very often becomes impure and harmful it is important that you learn something about the causes and how they may be prevented.

Wells are of two types, the dug or shallow well and the driven well. The dug well is generally used where the source of water is near the surface and only earth needs to be penetrated to reach it. A driven well may also be used in this way, but it is more frequently used where the source of water is far below the surface. Then rock, as well as earth, sand, and gravel, must be penetrated to reach it. Figures 95 and 96 show methods of making both types of well.

The cistern is a tank or reservoir into which rain water from the eaves of the house is run. Water is obtained from it by means of pumps. Since cistern water is not hard, it is excellent for cleansing use.

Water which seeps into the ground penetrates soil, sand, and in some cases layers of porous rock. In this way it is freed of many of its impurities. Such water will pass downward until it strikes solid rock, when it can go no farther. This forms what is commonly termed the *water table*. Water that has filtered through to the water table is not always pure because sewage and drainage from barnyards may also drain into it. Figure 97 shows the water table and how it may be contaminated[1] by drainage. Because of such danger, the placing of a well with respect to drainage is a very important matter. Study the conditions shown in Figure 97 and select the best place for a well. Why would you place it in this particular spot?

[1] *Contaminated*, infected; befouled; polluted.

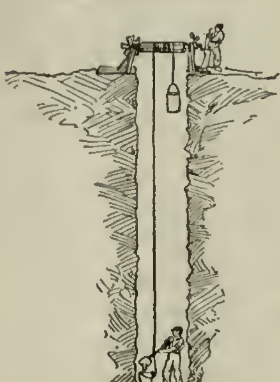


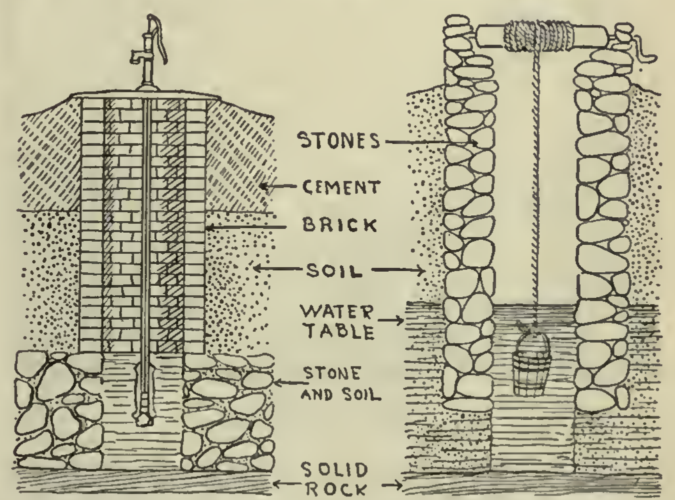
FIG. 95. MAKING A DUG WELL

FIG. 96. MAKING A DRILLED WELL

FIG. 97. A POORLY SITUATED WELL

The construction of a shallow well is as important as its location, inasmuch as a poorly constructed well may allow surface drainage to seep into it and make the water unfit for drinking. A properly constructed well of this type should have an uncemented wall extending up several feet from the bottom and cemented brick or stone the remainder of the way to the top. The curbing should be tight, permitting no surface water to drain into the well. Figure 98 shows a properly constructed shallow well and one of poor construction.

In many places deep driven wells are used for the water supply. These provide a satisfactory source because the water has been well filtered by soil, sand, gravel, and in some cases porous rock. Water will rise to the higher point in the water table when a pipe is driven down to its level. Figure 99 shows clearly how this happens.



WELL CONSTRUCTED WELL

POORLY CONSTRUCTED WELL

FIG. 98

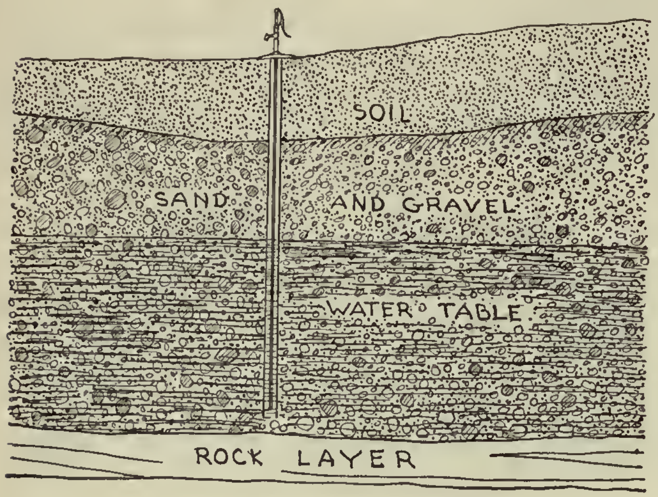


FIG. 99. DEEP DRIVEN WELL

Sometimes in a well driven in a valley, water comes from the pipe with such force that it rises several feet above the ground. This is spoken of as an *Artesian well.* The cause of this phenomenon is a peculiar dip in underlying rock layers. Water enters at high levels and is confined between two rock layers and moves toward the lowest point in the dip, as shown in Figure 100. When the top rock layer is penetrated near the lowest point of the dip, water spouts up because of the pressure of the water from the higher levels.

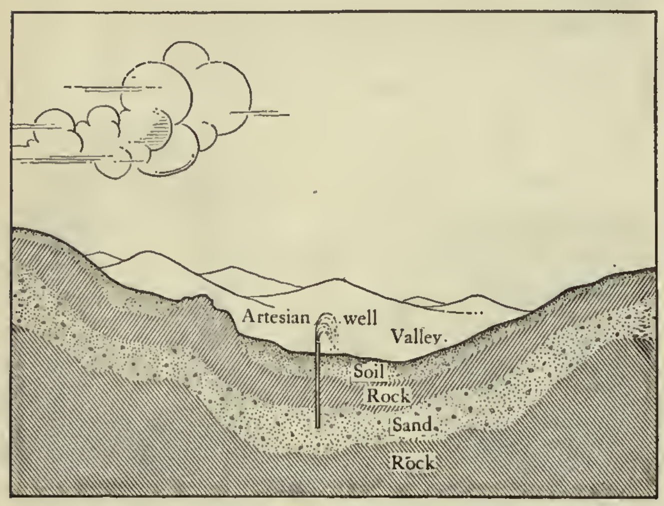


FIG. 100. ARTESIAN WELL

How are the inhabitants of large cities supplied with pure water? The location of a city usually determines how the water supply is secured. It is necessary, therefore, for us to study the water supply of several cities to obtain a clear idea of the various methods in use. For this study the cities of New York, St. Louis, Tucson, and Los Angeles have been selected because of distinctive features in their method of securing a water supply.

New York now has a population well over six million and is still increasing at a moderate rate. The average daily consumption of water in the city is more than 900,000,000 gallons. To insure the good health, in so far as water is concerned, of so many people, the city has been compelled to create one of the greatest water supply systems in the world. Water is collected from seven drainage areas which total more than 1,400 square miles of surface and is sent in some cases a distance of 125 miles to the city. More than twenty reservoirs provide storage capacity of 258,000 millions of gallons of water.

The water supply system of New York City dates back to 1842 when the Croton River was first used

Courtesy Board of Water Supply, New York City

FIG. 101. NEW CROTON DAM, NEW YORK WATER SUPPLY SYSTEM

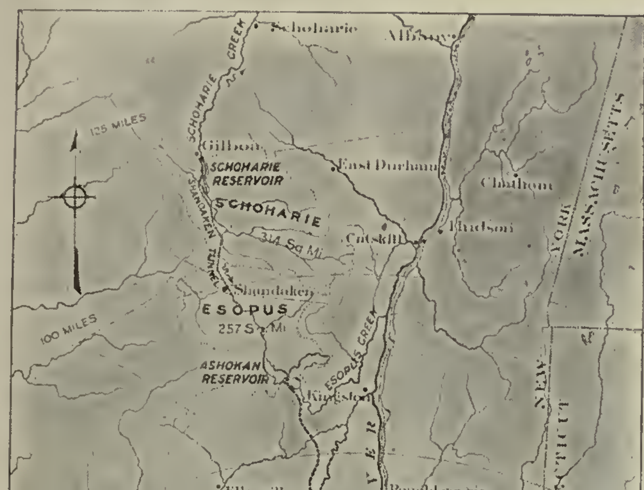
as a source. Water was gathered in two reservoirs and conducted a distance of fifty miles, through an aqueduct,[1] to the city. Since that time the Croton watershed has been developed until it now covers 375 square miles, draining into twelve storage reservoirs and six controlled lakes. Figure 101 shows a picture of one of the great reservoirs in the Croton system. Study the Croton watershed carefully, from the map, Figure 102.

More than thirty years ago it was observed that the Croton area would not long supply the amount of water demanded by the rapidly growing city. After careful investigation of various sources a plan was drawn to develop watersheds west of the Hudson River in the Catskill Mountains about 120 miles from the city. These areas are the present Esopus, Schoharie, and Catskill watersheds comprising about 600 square miles and capable of supplying 600,000,000 gallons of water daily to the city. (See Figure 102.)

The great Ashokan reservoir in the Esopus watershed has a capacity of nearly 130,000 millions of gallons of water. This amount of water would cover all

[1] *Aqueduct,* an artificial channel for carrying a large quantity of water which flows by gravitation.

of Manhattan Island (area, 22 sq. mi.) to a depth of thirty feet. Water from this reservoir is taken through ninety-two miles of aqueduct to the five boroughs of the city, where it is stored in large reserve reservoirs until needed. The map shows the Esopus watershed and the Ashokan reservoir connected to the city by the Catskill tunnel. Study the map carefully. Figure 103 shows a picture of the Ashokan reservoir.



Courtesy Board of Water Supply, New York City

FIG. 102. MAP OF NEW YORK WATER SUPPLY SYSTEM

The Catskill aqueduct which conducts the water from the Ashokan reservoir to the Kensico reservoir varies from fourteen to seventeen feet in diameter. Where this aqueduct goes under the Hudson River it was tunneled through solid rock at a depth of 1,100 feet below sea level. This great tunnel is capable of carrying 600,000,000 gallons of water to the city daily. The Esopus watershed supplies about 300,000,000 gallons a day.

To provide for recent growth of the city the great Schoharie watershed to the north of the Esopus area has been developed. This watershed contains about 314 square miles and is drained by Schoharie Creek, which flows northward into the Mohawk River. To change the flow of this creek a great dam has been built at Gilboa. This backs the water up so that it may be conducted by tunnel to Esopus Creek and then into the Ashokan reservoir. This great watershed is also capable of supplying upwards of 300,000,000 gallons of water daily.

In general the water supplied to New York City is very pure and requires only a limited amount of treatment. Just below the Ashokan reservoir provision has been made for jetting the water into the

Courtesy Board of Water Supply, New York City

FIG. 103. ASHOKAN RESERVOIR

air through about 1,600 nozzles. This process, called aeration, serves to mix the water thoroughly with the oxygen of the air, killing some bacteria and removing certain objectionable gases. This process is repeated at the Kensico dam. The water is also sterilized[1] with chlorine, thus assuring that most of the bacteria are killed. At times of heavy rainfall in some of the reservoirs the water becomes somewhat cloudy. Aluminum sulphate and soda ash are then added to settle the suspended matter more quickly. The water supplied in the New York area is very soft and frequently very active on iron pipes, causing them to rust rapidly.

This great water supply system is one of the best examples of how community health is guarded by pure water. It also illustrates the tremendous engineering problems that must frequently be solved before pure water may be supplied.

The city of St. Louis is located on the Mississippi River, about fifteen miles south of its junction with the Missouri River. The older part of the water supply system, known as the Chain of Rocks plant, is located on the Mississippi River about five miles

[1] *Sterilized*, made free from harmful bacteria.

below the point where the Missouri River joins it. Recently a part of an additional purification plant has been completed on the Missouri River, thirty-seven miles from the mouth and about twenty miles west of the city.

At the Chain of Rocks plant, water is taken from the Mississippi River through two intake towers and pumped to a delivery well on a higher level. From

Courtesy Board of Water Supply, New York City
FIG. 104. AERATION OF WATER

this point the water flows by gravity through the rest of the plant. Heavy grit and other suspended matter are removed in the grit chambers. After the water leaves the grit chambers a solution of milk of lime is added and thoroughly mixed in more than a mile and a half of conduit.[1] As the water leaves the mixing conduits and enters the settling basins a charge of iron sulphate is added to it. You will recall from the experiment that from the chemical interaction of milk of lime (calcium hydroxide or limewater) and iron sulphate, a green precipitate of iron hydroxide is formed.

$$\left.\begin{array}{c}\text{calcium hydroxide (soluble)}\\+\\\text{iron sulphate (soluble)}\end{array}\right\}=\left\{\begin{array}{c}\text{iron hydroxide (insoluble)}\\+\\\text{calcium sulphate (soluble)}\end{array}\right.$$

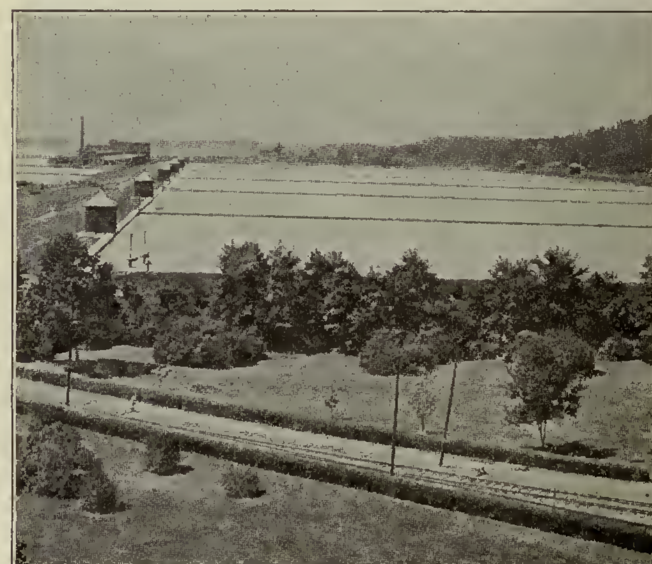
The water remains in the settling basins on the average about thirty hours, during which time the iron hydroxide precipitate settles to the bottom, carrying with it much of the larger suspended material. The settling basins are cleaned from time to time to remove the settled matter.

The water is collected from the settling basins in a conduit, and passes through meters where it is measured and a charge of aluminum sulphate (alum) is added. From the experiment you will recall that when limewater and aluminum sulphate react chemically an insoluble substance (precipitate) of aluminum hydroxide is formed.

$$\left.\begin{array}{c}\text{aluminum sulphate (soluble)}\\+\\\text{calcium hydroxide (soluble)}\end{array}\right\}=\left\{\begin{array}{c}\text{aluminum hydroxide (insoluble)}\\+\\\text{calcium sulphate (soluble)}\end{array}\right.$$

As the white aluminum hydroxide precipitate forms rather slowly, the water is run into another settling basin where the reaction is completed. Some of the precipitate settles out, carrying part of the remaining fine, suspended matter to the bottom. The water is then taken to the rapid sand filter where it passes through thirty inches of sand. Much of the aluminum hydroxide is caught on the filters, and thus their efficiency is increased to the point where even many of the larger bacteria are removed.

After filtration the water is sterilized with chlorine and sent into the city mains.



Courtesy St. Louis Dept. of Public Utility

FIG. 105. SETTLING BASIN, CHAIN OF ROCKS PLANT

In a single year 15,800 tons of lime, 1,900 tons of iron sulphate, 4,000 tons of aluminum sulphate, and 110 tons of liquid chlorine were used. It cost on an average of $9.15 to purify each million gallons, from which were removed 17,214 pounds of mud and 27,252,000,000,000 bacteria. The efficiency of the purification in the removal of bacteria is shown by the following table. These data are for 1929.

Bacteria in each cubic centimeter of river water	15,000
Bacteria in each cubic centimeter of settled water	1,100
Bacteria in each cubic centimeter of water to filter	190
Bacteria in each cubic centimeter of water to main	18

The new plant recently completed on the Missouri River makes use of about the same purification methods as the older plant. It is an excellent example, however, of how modern engineering is able to speed up processes.

Water is taken in from a shore intake and pumped

[1] *Conduit,* a channel, as a pipe, for conveying water.

to the rising well. Can you find this in the diagram shown in Figure 106? From this point water flows by gravity through the rest of the plant. It first flows to a pre-sedimentation basin where heavier grits are settled out. Lime is next added and rapidly mixed with the water as it flows past a series of baffles. After the iron sulphate is added, another rapid mixing occurs in a series of circular chambers. The water is then run into two settling basins where it remains for about two hours and then passes into two larger basins where the iron hydroxide continues to settle, carrying much suspended matter to the bottom with it. Both of these basins are equipped with continuous sludge-removing devices. Hence, it is unnecessary to drain them for cleaning.

After about thirteen hours of settling, the water is conducted to another basin. Here carbon dioxide, which is recovered from the smokestack gases and purified, is bubbled through the water. This tends to make the water softer and prevents scale from forming on the filters and in boilers which use this water. A charge of aluminum sulphate is next added to the water, mixed with it, and all is then taken to the rapid sand filters. Following filtration the water is sterilized with chlorine and conducted to an underground reservoir of five-million-gallon capacity. From this point the water is pumped to a large one-hundred-million-gallon reservoir about nine miles away. From this reservoir, about three hundred feet above the Missouri River level, water is distributed to the city by gravity.

Tucson, Arizona, located in the midst of the great western desert country, has a different problem of procuring a water supply from that of New York or St. Louis. To provide water for a population of 32,000 in desert country is a distinct problem.

With no rivers, lakes, or large watersheds close at hand, the city has drilled eighteen deep wells in the Santa Cruz valley, from which a clear, cool water without taste or odor is obtained. This water is pumped directly into the distribution system without the necessity of chemical treatment.

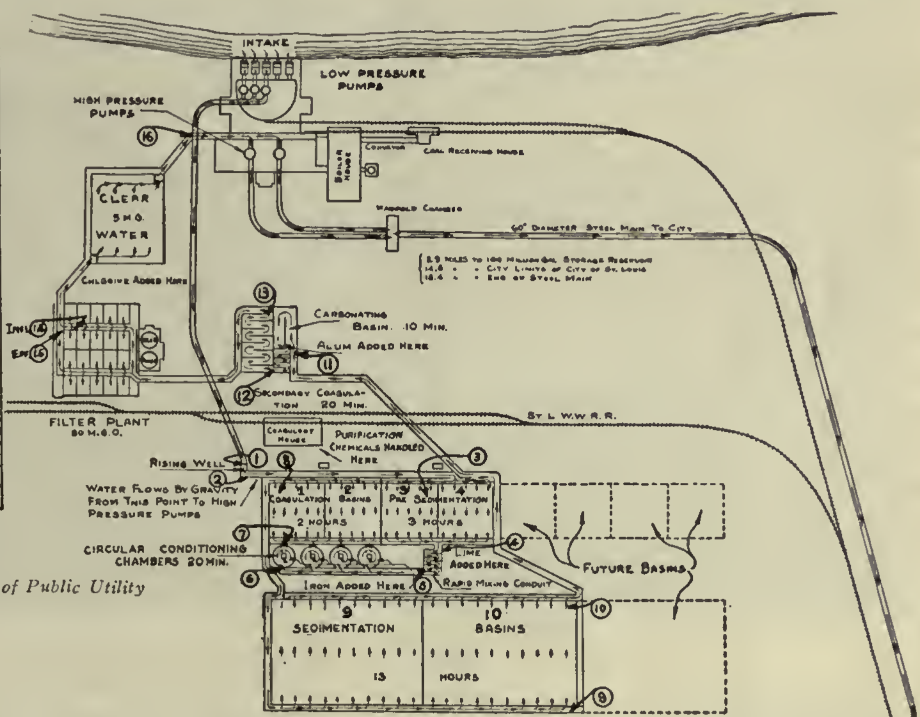
During the mild, warm winter days in this city, the average consumption of water is about 75 gallons per person per day, while during the hot summer months it rises to about 250 gallons per person per day.

In point of area Los Angeles is the largest city in the United States. Its boundaries enclose 441 square miles. Water is supplied at the rate of 160,000,000 gallons a day in this area all the way from sea level to an elevation of 1,400 feet. These two factors of area and elevation make the problem of water supply different from those of the other cities you have studied.

The Los Angeles River has been a source of water supply for the city for more than 150 years. Today it supplies about forty square miles of the city's area. Water is obtained from wells and from galleries placed below the river bed into which the water flows

ELEV. OF WATER IN SYSTEM
LS PUMPING 55 MGD.
FILTRATION 55 MGD.

STA.	ELEV.	LOSS OF HEAD
1	54.48	Feet
2	53.98	.50
3	53.08	.90
4	52.92	.16
5	52.21	.71
6	52.09	.12
7	51.38	.71
8	51.30	.08
9	50.87	.43
10	50.83	.04
11	50.42	.41
12	49.97	.45
13	49.96	.01
14	49.88	.08
15	38.98	10.90
16	38.72	.26
TOTAL H.L. THRU PURE PL.		15.76



Courtesy St. Louis Dept. of Public Utility

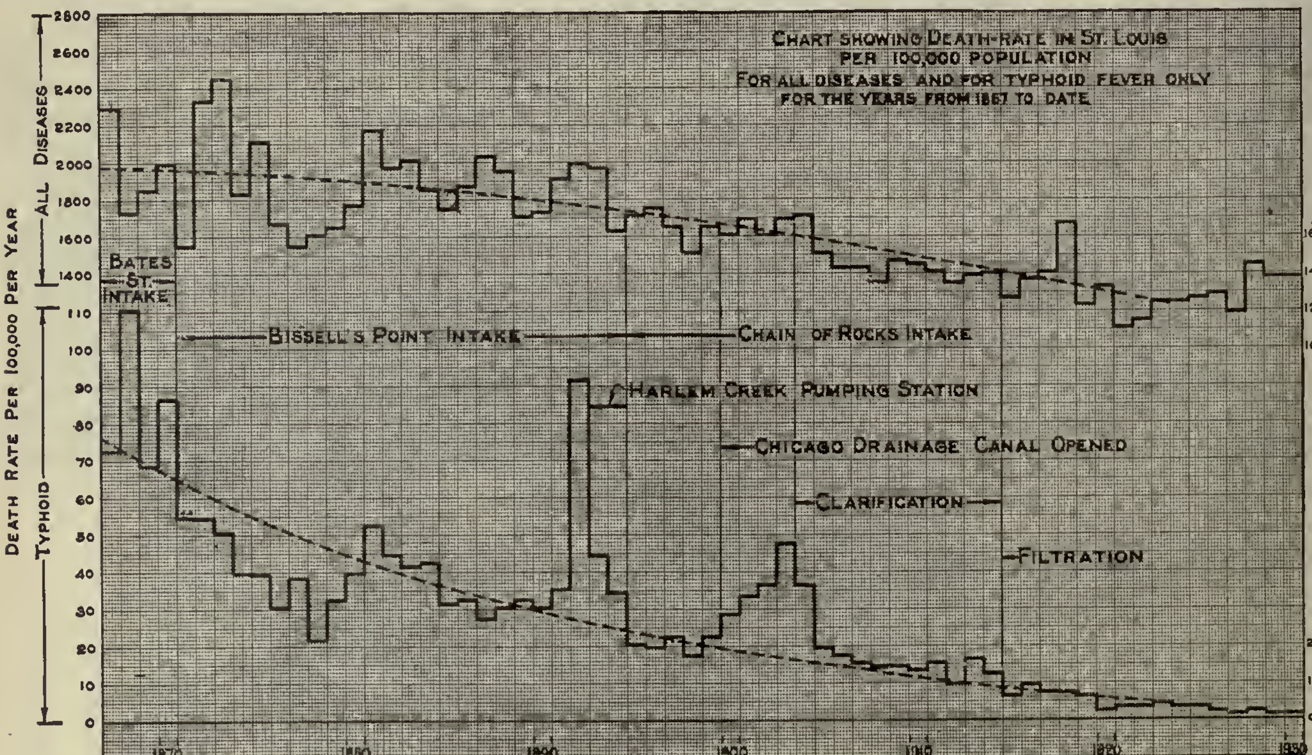
FIG. 106. DIAGRAM OF MISSOURI RIVER PLANT, ST. LOUIS WATER SUPPLY SYSTEM

after filtering through the gravel and sand. The deepest of these galleries is 180 feet below the river. The water is pumped from the galleries into storage reservoirs.

About twenty-five years ago it was observed that the Los Angeles River would not long be able to supply the demands of the rapidly growing city. After careful surveys had been made, the high Sierra Nevada mountain area was tapped by a 250-mile conduit which was completed in 1913 at a cost of $24,500,000.

From a point high up in the Owens Valley at the foot of Mount Whitney, the highest point in the United States, the waters of the Owens River are diverted[1] by the aqueduct and carried over the foothills of the Sierras, across the Mojave Desert and into Los Angeles. This aqueduct passes through 142 separate tunnels which total 53 miles in length. There are also twelve miles of inverted steel siphon, twenty-four miles of open, unlined conduit, thirty-nine miles of open cement-lined conduit, and ninety-seven miles of covered conduit.

Water from the Los Angeles aqueduct empties into twenty-eight storage reservoirs along its route and more than a dozen storage basins within the limits of the city. The combined storage capacity of all the storage reservoirs and basins is 38,124 million gallons. From the basins within the city the water is distributed to the consumer through 3,300 miles of water mains. Many pumping stations are maintained to supply adequate pressure to the many levels within the city.



Courtesy St. Louis Dept. of Public Utility

FIG. 107. GRAPH SHOWING DECREASE OF DEATH RATE IN ST. LOUIS

Since the water for this great system is supplied by melting snows and glaciers far away from the possibilities of pollution,[2] little has to be done to it to make it ready for use. Some problems are created by the growth of certain kinds of plant life in the reservoirs, but these are taken care of by adding copper sulphate to the water and covering the storage basins. The water is aerated to provide oxygen after its long journey from the mountains. Sterilization with chlorine is also used to kill any bacteria which may have got into the water. So high is the quality of Los Angeles water that there has not been a single case of water-borne disease in the city since 1902.

The intake of the Los Angeles aqueduct is at an elevation of 3,800 feet above sea level and it delivers water 700 feet above sea level. Thus in its journey from the mountains the water drops 3,100 feet. This provides opportunity for water-power development which has been taken advantage of by the city. Along

[1] *Diverted,* turned from the course.

[2] *Pollution,* contamination; impurity; uncleanness.

Courtesy Dept. of Water, Los Angeles

FIG. 108. OWENS VALLEY SYSTEM OF LOS ANGELES WATER SUPPLY

the aqueduct five electrical generating stations have been erected which furnish a total of 150,000 horse power of energy. As the water falls it is made to turn great turbines[1] which turn the electric generators. Thus a great city has supplied its water and much of its electricity by harnessing the water from the melting snows of the Sierra Nevada Mountains.

In 1920 Los Angeles was consuming eighty million gallons of water daily and in 1928 the amount had increased to 150 million gallons daily. This is an increase of 87 per cent in eight years. The Owens River project is capable of supplying 2,000,000 people. Los Angeles now has nearly 1,500,000 population and is growing at the rate of about 100,000 per year. Soon the present water supply will be inadequate and other sources must be found.

Engineers have already surveyed an area of about 18,000 square miles in an endeavor to locate the future water supply of the city. The survey showed that the Colorado River, 260 miles away, was the only source which could supply the demand. A gigantic aqueduct to the Colorado that will supply 7,500,000 people in and around Los Angeles with pure water is under construction. The project is scheduled for completion within a few years.

[1] *Turbines,* rotary wheel-like motors operated by the force of currents of water under pressure.

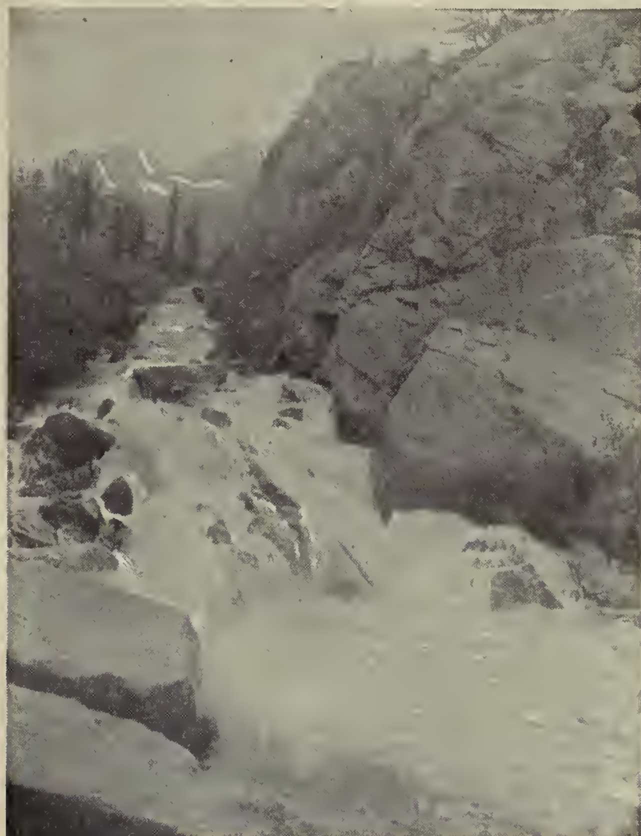
Of what importance is pure water to the health of a community? Thus far in the study of this topic you have seen how various types of communities secure pure water. It is not sufficient that just water be supplied, but for good health the water must be pure. Water supplies have frequently been the means by which diseases were spread. Probably the most dangerous disease from this point of view is typhoid fever. In the following exercises you will secure some first hand information bearing on this problem.

Exercise. *St. Louis secures part of its water supply from the Mississippi River. The sewage of Chicago reaches the Mississippi by way of the Chicago drainage canal and the Illinois River. Study the graph (Fig. 107) and answer the following questions about it in your notebook.*

1. *What was the death rate per 100,000 from typhoid fever in St. Louis in 1870?*
2. *Can you suggest from the data of the graph why the death rate dropped between 1870 and 1878?*
3. *What years on the graph might be marked as epidemic years.*
4. *Can you suggest a cause for the effect shown on the graph between 1898 and 1903?*
5. *What steps as shown in the legend of the graph have been taken by the city of St. Louis to control this situation?*
6. *What evidence can you cite from the graph to support the assertion that this condition has been effectively controlled?*

Exercise. *If you live in a rural area and secure your water from a well or spring, make a careful survey of your drainage conditions with respect to your water supply by means of the following guide. If you live in the city, survey some rural home which you have visited or know about.*

1. *Make a drawing in your notebook showing the location of the well or spring with respect to the toilet, the barn, and any other possible source of pollution.*
2. *As shown in your drawing, is there any drainage toward the water supply from the sources of pollution? Which ones?*
3. *If the source of supply is a well, what type is it—dug or driven?*
4. *Is the surface drainage such as waste water adequately taken care of, or does it drain back into the well?*
5. *What conclusions do you reach regarding the safety of this water with respect to pollution?*



Courtesy Dept. of Water, Los Angeles

FIG. 109. VIEWS OF LOS ANGELES WATER SUPPLY SYSTEM

Upper left—SOURCE OF SUPPLY
Middle left—OPEN CEMENT-LINED CONDUIT
Lower left—POWER PLANT GENERATING ELECTRICITY
Upper right—BACTERIOLOGICAL EXAMINATION
Lower right—CHLORINATION OF WATER

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 5

Clement, Collister, and Thurston, *Our Surroundings,* Chap. 5

Hunter and Whitman, *My Own Science Problems,* Unit 4

Lake, Harley, and Welton, *Exploring the World of Science,* Chaps. 6, 7

Pieper and Beauchamp, *Everyday Problems in Science,* Unit 5

Powers, Neuner, and Bruner, *The World around Us,* Chaps. 6, 7

Skilling, *Tours through the World of Science,* Tour 4

Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 5

Watkins and Bedell, *General Science for Today,* Chap. 4

Webb and Beauchamp, *Science by Observation and Experiment,* Units, 1, 3, 4 (parts)

Wood and Carpenter, *Our Environment: Its Relation to Us,* Unit 1; *Our Environment: How We Adapt Ourselves to It,* Unit 3; *Our Environment: How We Use and Control It,* Chap. 6

Special references

Garnett, *A Little Book on Water Supply*

Prudden, *Drinking Water and Ice Supplies*

Farmers' Bulletins, U. S. Department of Agriculture
No. 941, *Water Systems for Farm Homes*
No. 478, *How to Prevent Typhoid Fever*

Reports and miscellaneous bulletins from Water Commissioners of New York, N.Y.; St. Louis, Mo.; Tucson, Ariz.; Los Angeles, Calif.

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A realization of the importance of a pure water supply.
2. A knowledge of how various types of communities obtain an adequate supply of pure water.
3. A knowledge of the types of impurities found in water, their sources and dangers, and the methods used in removing them from water on a large scale.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the question, and comply with the instructions.

1. Water is composed of the two elements, ____ and ____.
2. Four different kinds of impurities found in water are ____.
3. What factors should you consider in determining whether a community has a good water supply?
4. Write a paragraph showing how New York City obtains pure water.
5. How are the problems concerned with providing St. Louis with pure water different from those of Los Angeles?
6. The most dangerous impurity found in water is usually ____.
7. Write a paragraph showing the things which one must consider in obtaining a supply of pure water in a rural district.
8. ____ is commonly used in the sterilization of water supplies.
9. When water contains a large amount of suspended material it is removed by a process called ____. In this process a substance which is (soluble, insoluble) ____ is formed chemically in the water. As this settles to the bottom it removes the ____.
10. Write a paragraph showing how pure water is obtained in your community.

TOPIC 3. USING WATER IN THE HOME AND COMMUNITY

SUGGESTED PROBLEMS AND QUESTIONS

1. **How is water distributed and handled in your home? What causes the pressure back of the water? How do faucets work? What is the purpose of a water trap?**
2. **How does water enable us to get rid of sewage? What are the dangers of improper sewage disposal?**
3. **What are the modern methods employed for sewage disposal? How is sewage disposed of in your community?**

SUGGESTIONS AND HELPS FOR STUDY

1. In connection with the first problem make a personal examination of the various devices employed to distribute and control water in your home and your schoolhouse.

2. Keep in mind that the problem of sewage disposal is closely related to the problem of water supply.

3. Make a survey of your local community to determine whether garbage, sewage, and human wastes are disposed of in a sanitary way.

4. Study the following words and see whether they are new to you.

antiseptic—a substance that prevents the growth of harmful organisms.

septic—producing decay through the action of certain kinds of bacteria.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 45. What are the factors that influence pressure in a water supply system?

Secure an old tin pail or a gallon can and punch a series of holes in it, beginning near the bottom and spacing them evenly toward the top. Fill the pail with water and observe it as the water flows from the different openings. Record the results of this experiment in your notebook.[1]

[1] See workbook, p. 26.

inferring what it shows about the depth factor and its influence on pressure. Devise a simple method of studying the effect of quantity of water in a reservoir on the pressure. Have your instructor approve your plan and then try it out.

Experiment 46. How much water is lost because of a leaking faucet?

Find a leaking faucet at home or in your school. If you are unable to locate a leaking faucet anywhere, allow a faucet to drip. Collect the dripping water for a half hour and measure the quantity. Calculate the quantity lost in one hour, the quantity lost in one day (twenty-four hours), and the quantity lost in one year. Find the cost of water in your city and calculate the loss in dollars for one year. Record your calculations in your notebook.[1]

Experiment 47. What are the types of faucets and how do they operate?

Three different types of faucets are used in homes and buildings: the screw type, the spring type, and the compression type. Try to find one of each type. Take them apart and examine them. Study the drawings of faucets in Figure 110. Record the results in your notebook.[2]

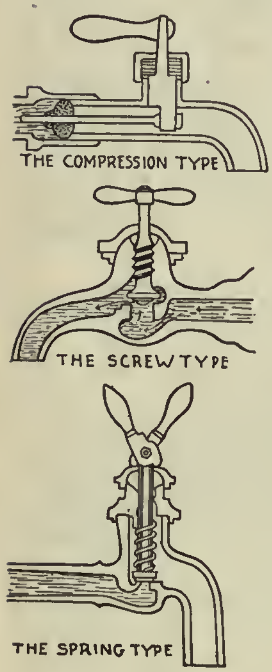


FIG. 110. THREE TYPES OF FAUCET

Experiment 48. How is a leaking faucet repaired?

Find a leaking faucet and repair it. Read the following statements carefully before you proceed.

a. Shut off the water. If no device for cutting off the water is provided underneath the faucet you will have to shut it off in the basement.

b. Open the faucet to make certain the water is shut off.

c. Unscrew the cap from the faucet.

d. Determine what type of faucet it is.

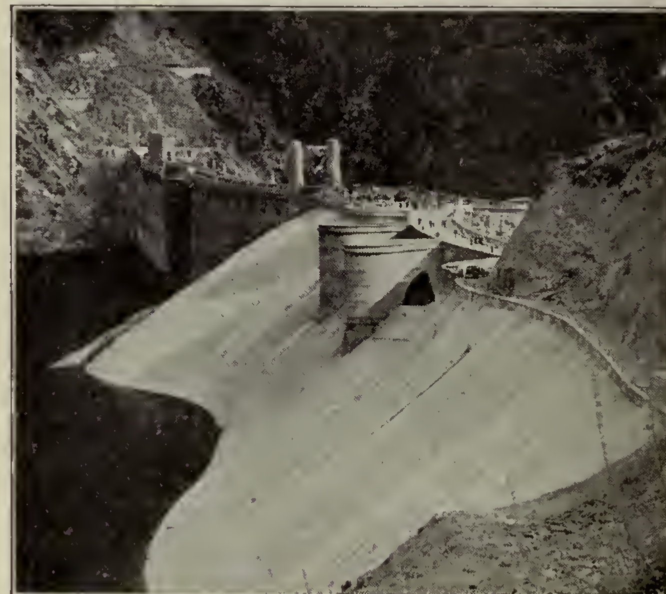
e. If it is a screw or spring type of faucet proceed as follows. Remove the valve. Remove the screw which holds the rubber or leather washer. Remove the old washer and fit in a new one. Replace the screw which holds the washer. Replace the valve and cap. Turn on the water and test the faucet.

f. The compression faucet requires a fuller ball, which can be purchased at a hardware store.

Record the results of this experiment in your notebook.[3]

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How is water distributed and handled in your home? Water must be furnished at sufficient pressure to force it to the tops of the highest buildings in the community. Cities like Denver and Los Angeles which are located near hills or mountains build reservoirs at a high elevation. The water flows in large pipes called mains by the force of gravity to the places in the community where it is used. In cities and towns not so fortunately located, stores of water are frequently pumped into standpipes or tanks. From the standpipes the water runs by gravity through the mains to the homes. In some large cities water is forced directly through the mains by force pumps.



International News Photos, Inc.

FIG. 111. DAM, SHOWING THICKNESS AT BASE

In the building of large dams like those that have been constructed in the past few years for irrigation and for electric power, the matter of water pressure is important. You have seen from your experiment that the pressure of water in a reservoir or behind a giant dam depends only upon the depth of the water and not at all upon the amount of water.

Exercise. *Study the photograph in Figure 111 and then write in the proper place in your notebook how the fact that water pressure is greater at greater depths has been provided for in the construction of the dam.*

FIG. 112. STANDPIPE

The faucets, pipes, and traps through which fresh water is circulated and wastes are carried away from our

[1] See workbook, p. 27.
[2] See workbook, p. 27.
[3] See workbook, p. 27.

dwellings are called the plumbing. The word "plumbing" is derived from a Latin word *plumbum*, meaning lead. However, iron and copper pipes as well as lead ones are used for plumbing. Generally iron pipes are galvanized (covered with zinc) to prevent rusting. New lead pipes may form substances which dissolve in water and which are injurious to the human body. When water has been standing in new lead pipes for a while it is best to let the water run at least a minute before using any of it. After lead pipes are used awhile they become covered with a coating that prevents further action of water on them.

FIG. 113. STORAGE TANK FOR WATER

Have you examined different types of faucets? Faucets are used to obtain water when we desire it and to stop the flow at other times. Study the diagrams in Figure 110 which show how three common types of faucets are operated. Every boy and girl should know how to repair a leaky faucet. Directions for doing this are given in one of the experiments at the beginning of this topic.

Have you ever noticed that the outlet pipe of a sink, a bathtub, or a washbowl is curved like a siphon? This bend in the waste pipe is called a trap (see Fig. 115). Water always remains in the trap and keeps the bad odors of sewer pipes from entering the house through the drain.

How does water enable us to get rid of sewage? The waste materials from the bathroom, the kitchen, and the laundry are called sewage. The problem of sewage disposal is closely connected with the problem of water supply. If sewage is not disposed of properly there is danger that some of it may get into the water supply and make the drinking water impure. Sewage contains many bacteria, some of which may produce diseases. Typhoid fever germs especially are apt to be present in sewage.

In rural districts the problem of sewage disposal is frequently left to each individual household. It is very unsanitary to throw waste water, food wastes, or human wastes upon the ground close to a dwelling place. Also the old-fashioned outside water-closet is undesirable. These methods of sewage disposal are especially dangerous if the drinking water is obtained from a well near the dwelling, for the water is likely to become polluted.

In country homes, not supplied with running water, an indoor chemical closet may be installed at a low cost. The wastes are deposited in a large pail that contains water to which is added a small amount of some chemical that kills germs and prevents undesirable odors. At certain intervals the pail is emptied

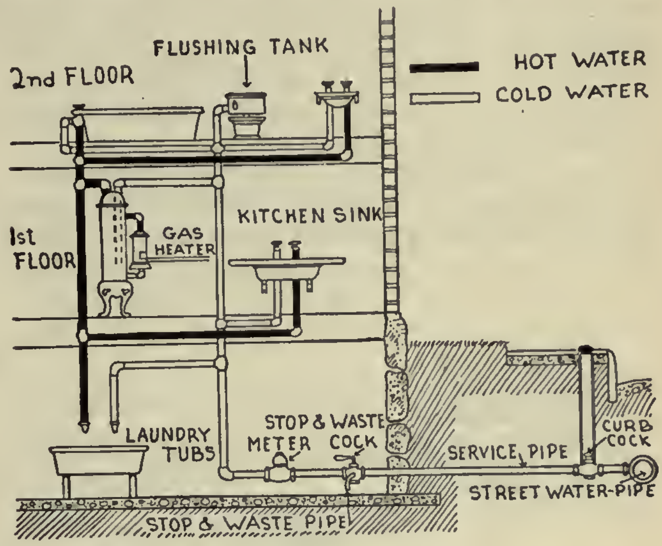


FIG. 114. HOUSE PLUMBING

into a hole in the ground. The wastes, being largely in liquid state, sink into the ground and are harmless.

The old-fashioned water-closet can also be replaced very cheaply by the dry-earth toilet. In a system of this kind the wastes are collected in a concrete

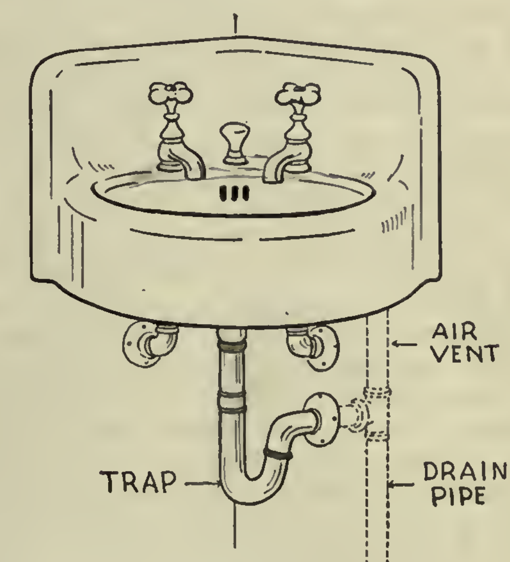


FIG. 115

vault instead of being deposited in a hole in the ground. The wastes are treated with a small quantity of chloride of lime (bleaching powder) and then covered with sand or earth. This treatment kills germs that may be present and prevents disagreeable odors. The dry contents of the vault can be removed whenever necessary without difficulty.

What are the modern methods employed for sewage disposal? In rural homes supplied with running water, the wastes are sometimes run into cesspools. A cesspool is merely a hole dug in the earth and loosely walled with stone or brick. The sewage which empties into the cesspool is slowly absorbed by the ground that surrounds it. This method of sewage disposal is not a desirable one, especially if the cesspool is placed near a well or a spring. Why?

A septic tank (Figure 116) is generally considered the most modern and efficient method to use for disposing of sewage. These tanks may be built of brick, concrete, or metal and may be divided into two or

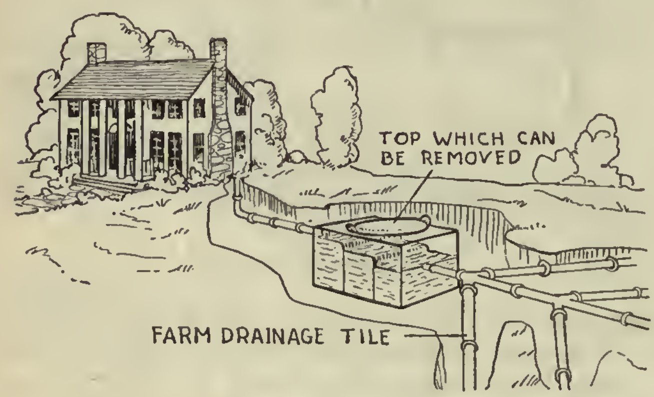


FIG. 116. SEPTIC TANK

more compartments. The compartments are so arranged that as the sewage passes slowly through them the waste matter is acted upon by certain bacteria. Solid substances are changed to liquids and gases, and germs are killed by the action of these bacteria. The liquid that finally flows from the septic tank into the soil is usually almost clear, free from offensive odors, and harmless. Any solid substances remaining are destroyed by the action of bacteria in the soil.

Perhaps the easiest method for disposing of sewage is to pipe it into the nearest body of water. Towns and cities along the seacoast generally pipe their sewage a considerable distance beyond the ocean shore. Since the quantity of wastes is small in relation to the large volume of ocean water, sufficient dilution and breaking up of waste materials occur to make them harmless. Inland cities on or near rivers and lakes find the disposal of sewage a more difficult problem. Untreated sewage, if dumped into streams, will not be purified because the body of water is too small. Thus the water becomes dangerously impure and endangers the lives of people living in towns and cities farther down the river.

Some large cities pipe their sewage into very large septic tanks which partly purify the waste. Then a disinfectant (a substance which kills germs) is added, and the liquid is drained into a body of water. In other inland cities the sewage is aerated before it is emptied into a river. First the solid matter is removed by screening. Then liquid wastes are pumped into fountains that spray it into the air. While in the air many of the germs are killed by the action of sunlight and oxygen. The liquids fall on beds of coke where bacteria continue the process of purification as the liquids filter through. Then the liquid may be finally filtered through a bed of sand or gravel which completes the purifying process.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 5
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 5
Hunter and Whitman, *My Own Science Problems*, Unit 4
Lake, Harley, and Welton, *Exploring the World of Science*, Chaps. 6, 7
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 5
Powers, Neuner, and Bruner, *The World around Us*, Chaps. 6, 7
Skilling, *Tours through the World of Science*, Tour 4
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 5
Watkins and Bedell, *General Science for Today*, Chap. 4
Webb and Beauchamp, *Science by Observation and Experiment*, Units 1, 3, 4 (parts)
Wood and Carpenter, *Our Environment: Its Relation to Us*, Unit 1; *Our Environment: How We Adapt Ourselves to It*, Unit 3; *Our Environment: How We Use and Control It*, Chap. 6

Special references

Knox, *All About Engineering*
Lynde, *Home Waterworks*
Williams, *How It Works*
Williams, *Romance of Modern Engineering*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of modern methods employed to distribute and handle water.
2. Skill in repairing leaky faucets.
3. An appreciation of the extensive uses of water in home and community life.
4. A knowledge of modern sanitary methods employed to dispose of sewage.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements and answer the questions.

1. What are the two most common types of faucets?
2. How does each type of faucet work?
3. What is the function of a water trap?
4. When the faucet is turned on, why does the water run out?
5. When a faucet leaks, it is usually because _____.
6. Two safe methods employed by cities to destroy sewage are _____.
7. If you were living in a country home not supplied with

running water, how would you dispose of sewage?

8. What is the chief danger from cesspools?
9. If a faucet is leaking, what is the probable cause?
10. Why are dams built thicker at the bottom than at the top?
11. What did you discover concerning the relation of water pressure and the amount of water in a reservoir? What does water pressure depend upon?

SUPPLEMENTARY MATERIALS

Reading suggestions

Butler, *Household Physics* (Barrows)
Lynde, *Physics of the Household* (Macmillan)
Tyndall, *Forms of Water* (Appleton)
Prudden, *Drinking Water and Ice Supplies* (Putnam)
Clarke, *Boys' Book of Chemistry* (Dutton)
Garnett, *A Little Book on Water Supply* (Macmillan)
Beebe, *Half Mile Down* (Harcourt)
Bishop, *The Story of the Submarine* (Century)
Holway, *The Story of Water Supply* (Harper)
Thompson, *Water Wonders* (Grosset)
Bashore, *The Sanitation of a Country House* (Wiley)
Abbot, *Everyday Mysteries* (Macmillan)
Bond, *On the Battlefront of Engineering* (Century)
Bond, *With the Men Who Do Things* (Scientific American)

Reports which may be prepared

1. The work of the Department of Public Health of your state in protecting the water supplies
2. The sewage disposal system of your community
3. How the water of your community is purified
4. The disadvantages in the use of hard water
5. The conservation of water supplies
6. Bacteria found in water supplies
7. Better methods of sewage disposal
8. Water for the farm home
9. Water systems for the farm
10. Securing water pressure in a water system
11. The various types of pumps
12. Water supplies in foreign countries
13. The Roman aqueducts
14. The water cycle in nature
15. Uses of the hydraulic press
16. The building of modern dams
17. Divers and their equipment

Great scientists you should know about

Archimedes
Blaise Pascal

Investigations and things to do

1. Learn to read a water meter.
2. Examine a flush tank and locate the ball, plunger, and siphon. Determine the work of each part.
3. Make a survey study of your home and prepare a diagram showing how water is distributed and controlled.
4. Make a survey study of your community and report any unsanitary conditions that you find which may be endangering the health of its citizens.
5. Repack a leaky faucet with a new washer or fuller ball. Be sure that the water is first turned off.
6. Secure samples of hard water and remove the hardness.
7. Visit the water supply of your city or town or one nearby.
8. Make a model of a hydraulic press.

UNIT IV. OUR FOOD SUPPLY

Eating is one of our most important activities. Our bodies are in some respects like machines. We need a supply of energy to keep going; parts of our body must be repaired from time to time and new parts must be built. Our bodies differ from machines in that the human body can repair and strengthen its own parts while machines must be rebuilt and repaired by a mechanic.

Nearly everyone knows that food makes these things possible, but do you know that foods vary greatly in their ability to furnish energy and materials for growth and repair? Chemists analyze foods and find that there are different constituents[1] in them and that the percentages of the different food nutrients[2] in foods vary tremendously. In fact, some foods may be entirely lacking in one or more of the food nutrients.

We also know that the foods we eat should be selected carefully. In order to have healthy bodies we must have not only enough food but also the proper amounts of the various food nutrients. When both of these conditions are satisfied our diet is properly balanced.

[1] *Constituent,* a necessary or essential part.

[2] *Nutrients,* substances which furnish food to the body.

In this unit you will learn about how our food is produced, of what it is composed, what the use of each kind of food is, how much of each kind of food we should eat, how to prepare and preserve food, and finally how food is digested and assimilated by our bodies. This knowledge will help you live happy and healthful lives.

What do you already know about food? Write the answers in your notebook.

1. Why do all living things need food?
2. Why do you eat different kinds of food?
3. Where do the foods used by the people in your community come from?
4. Why are many foods cooked before we eat them?
5. What causes foods to spoil?
6. How do we keep foods from spoiling?
7. Why is milk considered a nearly perfect food?
8. How does your body digest and assimilate food?
9. How is milk pasteurized?

TOPIC 1. MAN'S NEED OF FOOD

SUGGESTED PROBLEMS AND QUESTIONS

1. **Why must we eat food?**
2. **How do we grow?**
3. **Why do we need energy?**
4. **What are the sources of our food?**
5. **How do plants manufacture food?**
6. **What are the factors that control our food supply?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems listed above and see if they are questions which you have wondered about or are interested in.

2. To answer problem 5 write a paragraph explaining the process of food manufacture in plants. Compare food manufacture in plants with a commercial manufacturing process.

3. The following words may be used in this topic. If they are new to you, study them carefully and use them as often as possible.

osmosis—the process by which roots of plants take in water.

photosynthesis—the process by which food is made in plants. *Photo* means light. *Synthesis* means building up.

chlorophyll—the green-colored material in leaves.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Activity 49. Where do our foods come from?

In your notebook list all the different foods that you have eaten for several days. In list 1 name the foods that were obtained from animals. In list 2 name the foods that were obtained from plants. In list 3 name foods which came from neither plants nor animals.

Activity 50. What parts of plants and animals do we eat?

In your notebook make lists to show the parts of the plants and animals from which the foods listed in Activity 49 came. For the plant foods list whether it was from root, stem, leaf, flower, fruit, or grain. For the animal foods list whether it is muscle, fat, muscle and fat, or the entire animal such as an oyster.

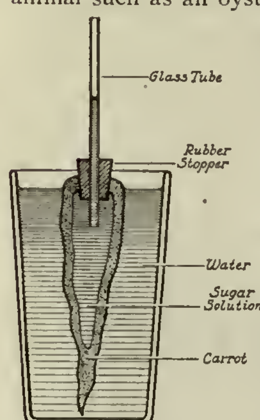


FIG. 117
CARROT OSMOMETER

Experiment 51. What is osmosis?

Secure a carrot or a sweet potato. Set up a carrot or sweet potato osmometer as shown in Figure 117. The rubber stopper must fit into the carrot closely. Fill the cavity in the carrot with strong sugar solution. Seal the stopper to the carrot with wax. Place in a jar of water. Allow the osmometer to stand for twenty-four hours and observe what happens.

In your notebook state the inferences which you draw from this experiment.

[1] See workbook, p. 29.

Experiment 52. Do green leaves of plants manufacture starch?

First learn how to test for starch. Make a starch paste with a pinch of starch and some water and put some of it into a test tube. Mix a few drops of iodine solution with the starch paste. What color is formed? Record the notes of this experiment in your notebook.[1] This experiment is the test for starch.

Now obtain several leaves from a healthy plant which has been exposed to direct sunlight for several hours. Boil the leaves for a few minutes in water and then boil them in alcohol until they are nearly white. The green matter in the leaves will come out into the alcohol. Place the leaves in water again and heat them gently until they are soft. Remove one of the leaves from the water and put several drops of iodine solution on it. What color appears in the leaf? What do you conclude from the experiment? Record your notes in your notebook.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Devise an experiment to show that gases are given off by leaves of green plants.
2. Devise an experiment to show that water is given off to the air by leaves of green plants.
3. Pull up a flowering plant and examine its roots, stem, leaves, and flowers. Find out the function of each of these parts.
4. Devise an experiment to determine the parts of a stem through which water rises from the roots. *Suggestion:* Use a stalk of celery.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Why must we eat food? Every living creature from the lowest to the highest form of life must have food. Because of the great importance of food to plants and animals and because of the many varieties of living things many special methods have been developed by them for obtaining food and disposing of it after it is secured. In this unit of study we shall have time enough only to see how food is obtained, prepared, digested, and used by man.

Scientists tell us that we must eat food for three reasons. First, the human body must have a continual supply of energy to keep it working. It is like a steam engine in this respect. You know that in a steam engine the burning of coal produces heat energy which generates the steam that runs the engine. In the human body food is "burned" and furnishes energy in the form of heat. Second, our bodies grow, and foods supply the substances necessary for growth. Third, the body must repair worn-out parts with substances obtained from food.

How do we grow? The human body is made up of countless millions of tiny units of living matter called *cells*. (See Fig. 118.) If a compound microscope is available in your school and you wish to see a cell, carefully scrape some material from the inside of your cheek, place it on a glass slide, add a drop of water, and examine it under the microscope.

Each individual cell helps to do the work of the body. It receives the digested food, changes it into living matter, and grows. When the cell reaches a certain size it divides and forms two cells. When these

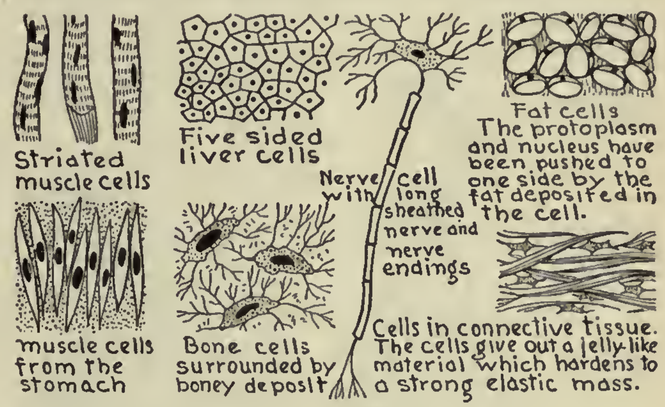


FIG. 118. CELLS OF THE HUMAN BODY

two cells have grown to the same size as their parent cell they also divide (Fig. 119). It is by this constant dividing of cells that our bodies increase in size, and the life of the human body is the combined life of its individual cells.

Why do we need energy? Our lives are made up of activities. During the daytime we may walk, run, jump, play, or work. At night when we are asleep we are more quiet, but even then our heart is pumping blood to all parts of the body. Our chest rises and falls as we breathe. Muscles of our digestive system

FIG. 119. THE DIVISION OF CELLS

are at work aiding the process of digestion. The food that we eat is oxidized by the oxygen in the air that we breathe, thus providing the necessary energy to our bodies in the form of heat. Our bodies remain constantly at a temperature of 98.6° F. when we are well. When the temperature of our body rises or falls even one degree from this point the variation is an indication of sickness.

What are the sources of our food? By looking carefully over the list of foods that you eat you will notice that they can be grouped first of all into two classes: those that we obtain directly from plants and animals, and those like water and salt that we get from non-living things. The foods from plants and animals are called *organic* foods; the foods from non-living things are called *inorganic* foods.

Most of our foods are of the organic type, that is,

[1] See workbook, p. 29.

they come from plants and animals. This is obvious when we consider the large quantities of fruits, vegetables, and cereals (all plant products) that we consume, plus additional quantities of meat, milk, cheese, eggs, and butter, which are animal products. Though we need less of the inorganic materials in our diet, they nevertheless are important, as we shall learn in a later study.

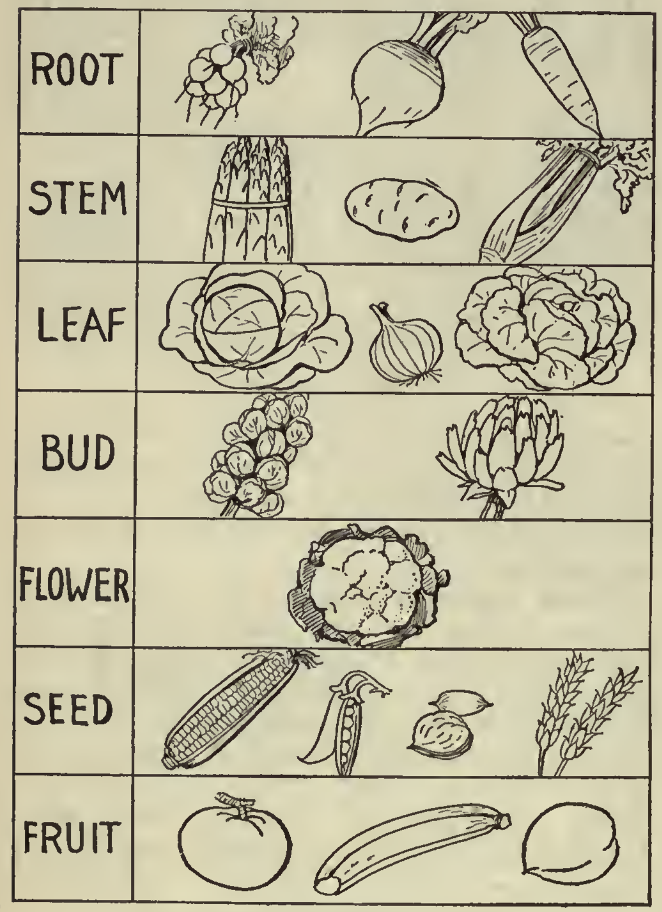


FIG. 120. PARTS OF PLANTS USED AS FOOD

How do plants manufacture food? The greater part of our daily diet consists of plants. The enormous quantities of plant foods consumed each year make agriculture a basic industry of our country.

It is very seldom, however, that we eat an entire plant. It is usually only the root, the stem, the leaf, the fruit, the grain, or the flower that is used as food. In the following table are listed some common foods and the part of the plant which we consume. Perhaps you can add many more examples to the list.

FOOD	PART OF PLANT EATEN
sweet potato	root
Irish potato	underground stem
tomato	fruit
lettuce	leaf
cauliflower	flower
turnip	root
corn	grain
cabbage	leaf
onion	leaf
beans	fruit
asparagus	stem
radish	root
banana	fruit
walnut	fruit

All of the food of the world is made by plants. Although we eat meat from animals, these animals depend upon plants for their food. Plants are the only living things that are able to change inorganic substances into living matter. It is for this reason that plants occupy a position of supreme importance in the living world. Without them animal life could not exist, for animals cannot make food—they simply consume it.

Let us see now how plants carry on food making.

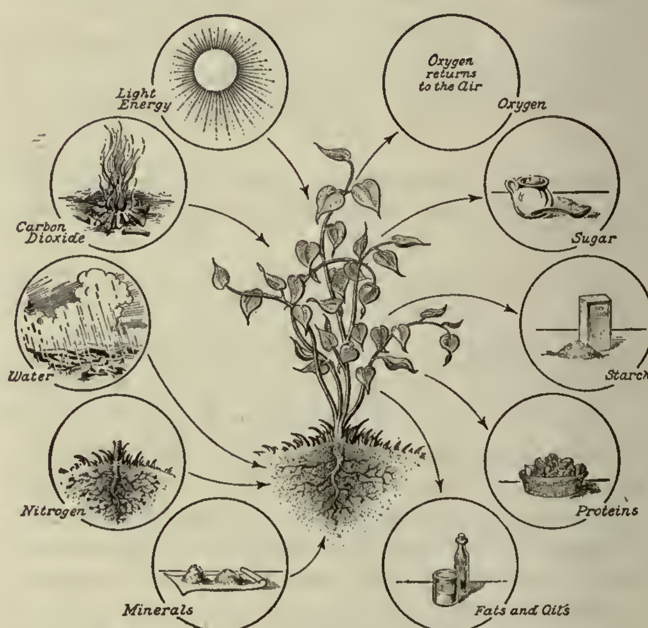


FIG. 121. PLANTS ARE THE FOOD FACTORIES OF THE WORLD

The roots, stems, and leaves are all involved. The roots take water from the soil and with the water they take minerals which are dissolved in it. This water passes up through the stems to the leaves. In the leaves are tiny openings through which air enters and in the air is a gas called carbon dioxide. The leaves contain a green substance called *chlorophyll* which, with the aid of sunlight as energy, combines the water and carbon dioxide into carbohydrates (starch or sugar). Biologists call this process *photosynthesis*. Oxygen is given off to the air during this process, thus maintaining an adequate supply of oxygen for living things. One of the best ways to learn and understand photosynthesis is to compare it with

a manufacturing process. The two processes may be compared as follows:

factory—green leaf
work rooms—cells in the leaf
machinery—chlorophyll
energy—light
raw materials—soil water and carbon dioxide
product—carbohydrates (starch and sugar)
by-product—oxygen

From the carbohydrates plants can produce other substances such as fats, oils, and proteins.

What are the factors that control our food supply? You have learned that most of our food comes either directly or indirectly from plants. Plants are living things and as such must have favorable conditions under which to grow. Among these factors are proper temperature, sufficient soil moisture, fertile soil, and sunlight. Let us consider the importance of each of these factors in crop production.

It has been found that seeds germinate better and crops grow faster when soil temperature is between 65 and 75 degrees Fahrenheit. It is possible for man to influence and control soil temperature to a certain degree. If manure is added to the soil a certain chemical change is brought about by microscopic organisms called bacteria. This chemical change produces a certain amount of heat, some of which is useful in warming the soil. In the unit on weather you learned that the process of evaporation is a cooling process. This process is important in the regulation of soil temperature. If moisture is permitted to evaporate from the ground surface, it absorbs heat from the soil and as a result cools it. Evaporation of soil moisture is prevented by cultivation and mulching.

Another important factor in crop production is the proper amount of soil moisture. Everyone has observed that plants and crops vary in the amount of soil moisture that they require. The willow tree usually grows where there is an abundance of water in the soil while the cactus may grow where there is relatively little. Most of our farm and garden crops fall between these two extremes. Water commonly exists in soil either as a film around the soil particles or by filling the spaces between them.

Providing the proper amount of soil moisture presents a different problem in various sections of the country. For example, in certain sections there is an over supply of water, and some of it must be drained away. In other places the rainfall is so light that moisture must be supplied by irrigation.

If crop production is to be kept at the highest possible point, the fertility of the soil must be maintained. As you have learned, plants take their nourishment from the soil. This withdrawal tends to remove certain important mineral substances which must be replaced if the fertility of the soil is to be maintained. Nature has provided certain ways in which some of the used substances may be replaced, but certain others must be replaced through fertilizers by man. You will learn more about these processes in a later unit of this book.

It is important that crops have sunlight not alone for the heat which it gives to the soil but also, as you have learned, because plants need the energy of sunlight to build food.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 35
Clement, Collister, and Thurston, *Our Surroundings,* Chaps. 26-33
Hunter and Whitman, *My Own Science Problems,* Unit 11; *Science in Our World of Progress,* Unit 15
Lake, Harley, and Welton, *Exploring the World of Science,* Chaps. 26, 27
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 4
Powers, Neuner, and Bruner, *The World around Us,* Chap. 22; *This Changing World,* Unit 6; *Man's Control of His Environment,* Chap. 28
Skilling, *Tours through the World of Science,* Tour 19
Van Buskirk and Smith, *The Science of Everyday Life,* Unit 3
Watkins and Bedell, *General Science for Today,* Unit 11
Webb and Beauchamp, *Science by Observation and Experiment,* Units, 4, 8 (parts)
Wood and Carpenter, *Our Environment: Its Relation to Us,* Unit 8; *Our Environment: How We Use and Control It,* Chap. 18

Special references

Atwood and Heiss, *Educational Biology*
Kinne and Cooley, *Food and Health*
Sanford, *The Story of Agriculture in the United States*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The scientific reasons why we eat.
2. The sources of our food supply.
3. A knowledge of how plants make food.
4. The concept that animals are dependent upon plants, the only living things that can build up food.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. What are the three main services performed by food?
2. For each of the following foods, name the part of the plant in which the food is stored; for example, sweet potato—root.

Tomato, apple, banana, potato, lettuce, cauliflower, radish, turnip, corn, beans, cabbage, onion, carrot, walnut.

3. Food is manufactured by ____.
4. The green substance present in the leaves of green plants is called ____.

5. Soil water and minerals enter plants through the ____ by a process called ____.

6. Food is manufactured by plants principally in the ____.

7. Green plants with the aid of sunlight manufacture food from the raw materials ____, and ____ is given off as a by-product. This process is called ____.

8. Can you suggest a method to prove that oxygen is given off as a by-product of the process of photosynthesis?

9. Suggest a method for testing the importance of sunlight in the process of photosynthesis.

10. Show how the process of osmosis might be of importance in the absorption of food in the human body.

11. On the basis of your knowledge of osmosis, predict what would have to happen to such a food as cooked egg before it could be absorbed into the blood stream.

12. How would you prove by experiment that water vapor is given off by green plants?

13. Suggest a way of proving that water rises to the leaves of a plant through the stem.

14. What are the four most important factors which control our food supply?

TOPIC 2. IMPORTANCE OF A BALANCED DIET

SUGGESTED PROBLEMS AND QUESTIONS

1. **How many classes of food substances are there?**
2. **What is the work of vitamins? How are vitamins classified and what is the principal function of each kind?**
3. **How should we select our food?**
4. **Why is milk sometimes called the perfect food?**
5. **How can we provide ourselves with pure milk?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully read the problems listed above to be sure that you understand them before you begin your reading and investigation.

2. Work out a balanced diet for three meals a day for several consecutive days.

3. Many of the general science textbooks give tables or charts showing the percentages of the different food nutrients in common foods and also the principal vitamins found in each. Consult these tables and charts freely.

4. If the following words are new for you, study them carefully until they become a part of your vocabulary.

nutrients—substances which furnish food to the body.

protein—food material containing carbon, hydrogen, oxygen, and nitrogen. Meat and eggs contain a large amount of protein.

elements—substances, such as iron, gold, copper, oxygen, which cannot be broken into anything simpler.

carbohydrate—group of compounds containing carbon, oxygen, and hydrogen, as sugar and starch.

vitamins—regulative food substances necessary to life.

bacteria—tiny one-celled plants.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 53. How do we test for starch in foods?

Bring to class small quantities of the following foods: white potato, sugar, lima beans. Dissolve a few crystals of iodine in alcohol to make a weak iodine solution. The tincture of iodine, obtainable at the local drug store, may be used. White potatoes have large amounts of starch in them. Put a few drops of the iodine solution on the peeled potatoes.

In your notebook[1] record the results of your experiment, answer the following questions, and complete the statement.

What color appears? If you put a few drops of iodine solution on the sugar, what happens?

Remove the outer shell of a lima bean and put a few drops of iodine solution on the inside of the bean. Do lima beans contain any starch?

When a food containing starch is tested with an ____ solution a ____ color appears.

Experiment 54. How do we test for sugar in foods?

Obtain bottles of Benedict's solution.[2] Place a small amount of Karo in a test tube. Add a small amount of water. Heat gently until the Karo is mixed with the water. Now pour into the test tube a small amount of Benedict's solution. Heat the mixture in the test tube to the boiling point. Repeat this procedure with samples of various foods, such as raisins, grapefruit, and prunes. Record the results in your notebook.[3]

When the mixture of sugar solution and Benedict's solution was heated the color changed from ____ to ____. This is a test for ____.

Experiment 55. How do we test for proteins in foods?

Put a small piece of raw meat into a test tube, add a little water, and boil. Next add a little nitric acid (strong solution). Drain the nitric acid from the tube and add cautiously a small amount of ammonium hydroxide, a few drops at a time. What color appears? This is the protein test.

Repeat this test on samples of other foods. In your notebook[4] record your results and complete the statement.

Proteins in the presence of nitric acid and ammonium hydroxide form a ____ coloration.

Experiment 56. How do we test for fats and oils in foods?

Put a piece of fat meat into a test tube, add ether, and let it stand for awhile. As ether is very inflammable, it should not be used near open flames. The ether will dissolve the fats. Pour off the ether from the meat and evaporate.

[1] See workbook, p. 30.

[2] Directions for making Benedict's solution are in the teacher's manual.

[3] See workbook, p. 30.

[4] See workbook, p. 30.

What is left after the ether evaporates? Foods that are abundant in fat usually will leave a clear spot on thin paper when the food is applied to it.

Try this test on several fatty foods.

Record the results in your notebook[1].

Experiment 57. How is milk pasteurized?

Secure two bottles of equal size. Place the two bottles in a dish of water and boil for at least twenty minutes. This will kill all bacteria present in the bottles. Plug the mouths of the bottles with absorbent cotton and stand them aside to cool. Put some raw milk into a vessel and heat to about 145° F. Keep stirring the milk with a thermometer and keep the milk at this temperature about thirty minutes. Pour the pasteurized milk into one of the sterilized bottles and plug it with fresh absorbent cotton. Cool it with running water. Put an equal amount of raw milk into the other sterilized bottle and plug with fresh absorbent cotton. Put them aside and examine them from time to time.

Which milk turns sour first? Why is milk pasteurized? Record the results in your notebook.[2]

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Keep a record of the foods you eat each meal for three days. Check your diet for the following:
   - proportions of the various food nutrients
   - vitamin content
   - mineral content
   - amount of water
   - entire amount of food

   What improvements can you make in your diet?
2. Prepare lists of common foods rich in
   - carbohydrates
   - proteins
   - vitamins
   - minerals
3. Make a study of the relative costs of the foods in the lists compiled in the preceding problem.
4. Examine a drop of milk under the microscope.
5. Study the methods used in caring for milk in your community.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Chemists have analyzed matter, both living and lifeless, and they tell us that there are ninety-two different elements which combine in various ways to form all the different kinds of materials in the universe. The bodies of living things, with few exceptions, are composed of combinations of about twelve of these ninety-two elements. The composition of the human body is approximately as follows:

ELEMENT	PER CENT IN BODY	ELEMENT	PER CENT IN BODY
Oxygen	65.0	Potassium	0.35
Carbon	18.0	Sulphur	0.25
Hydrogen	10.0	Sodium	0.15
Nitrogen	3.0	Chlorine	0.15
Calcium	1.5	Magnesium	0.05
Phosphorus	1.0	Iron	0.004

[1] See workbook, p. 30.

[2] See workbook, p. 31.

Thus we see that the body of man is composed of common elements of the earth.

How many classes of food substances are there? The foods we eat are composed of six classes of food substances, namely, carbohydrates, fats and oils, proteins, mineral matter, water, and vitamins.

Carbohydrates are chemical compounds made from three elements: carbon, oxygen, and hydrogen. Sugars and starch are carbohydrates and are found in the bodies of plants and animals. We obtain these food nutrients chiefly from potatoes, bread, rice, and ripe fruits.

Fats and oils are made of the same chemical elements as carbohydrates. They differ from carbohydrates in

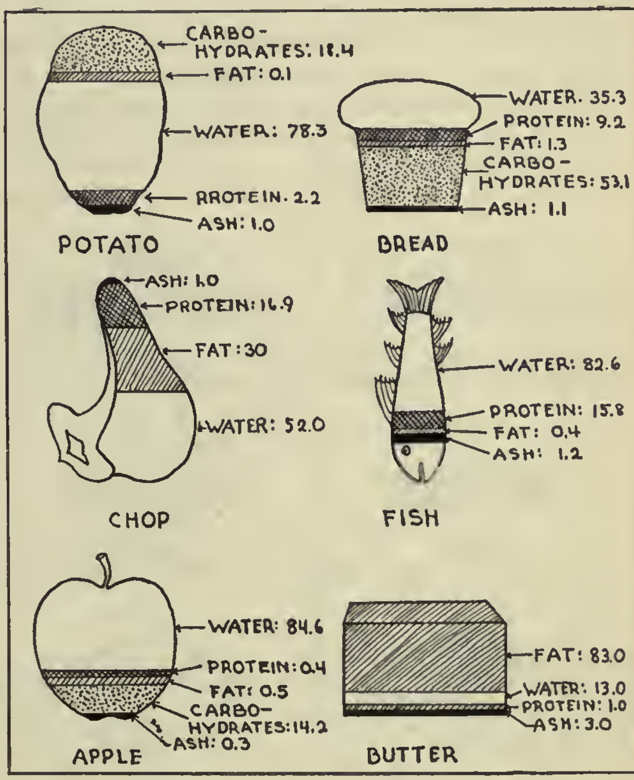


FIG. 122. WHAT OUR FOODS ARE MADE OF

that the elements are present in different proportions. They are our best energy-giving foods because they combine with oxygen more easily than carbohydrates and proteins do. Butter, milk, lard, oleomargarine, nuts, and food preparations made from nuts are our principal sources of fats and oils.

Proteins are always made of the elements carbon, oxygen, hydrogen, and nitrogen and ofttimes have in them smaller quantities of sulphur, phosphorus, or iron. Lean meat, fish, eggs, milk, beans, peas, and bread are our principal sources of proteins.

In addition to the nutrients (carbohydrates, fats, and proteins) our bodies must be supplied with adequate amounts of minerals and water. Minerals are especially needed in the making of bones, teeth, and

blood. They are present in fruits, vegetables, and milk; we also take minerals more directly in salt.

Chemical analysis shows that the human body is more than 65 per cent water. Water carries dissolved foods in the body and is necessary for the removal of waste matter. Although fruits, vegetables, and milk contain large quantities of water we need to drink additional amounts. The amount needed depends largely upon climate and occupation. In warm weather we need to drink more than in cold weather because evaporation of water is going on faster from the surface of our bodies. We should always drink plenty of water, for there is no danger that we shall drink too much. Many physicians recommend at least six glasses a day.

What is the work of vitamins? Vitamins are substances that help to regulate physical growth and health. Scientists have not yet been able to determine the exact chemical nature of them, but their

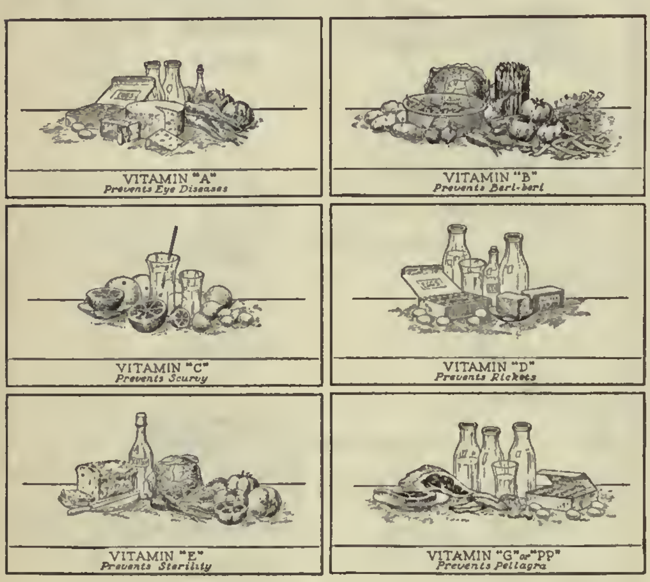


FIG. 123. FOODS RICH IN VITAMINS

sources are known and also the effects they produce in the body. They are named by letters of the alphabet.

Recent experiments seem to indicate that vitamins are in some way built up in the leaves of green plants. They are found in such foods as milk, butter, and eggs because cows and chickens are fed on foods derived from plants which contain vitamins.

Vitamins A and D are quite abundant in milk, butter, yolk of eggs, and cod-liver oil. Vitamin A is present also in green vegetables. Vitamin A is known to help in the development of the eyes and to keep them free from diseases. Vitamin D prevents rickets. This is a disease in which the bones of growing children soften. The ultra-violet rays of sunlight have the same effect as the vitamin on children, and because of this fact vitamin D has lately been called the *sunshine vitamin.* Science has learned recently how to establish vitamin D in foods artificially by means of ultra-violet rays. Several foods, including milk, treated by this process have appeared on the market recently.

Recently it has been found possible to produce vitamin D artificially in the human body by means of

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FIG. 124. VALUES OF VITAMINS IN ANIMAL DIET

Illustrations on the left show effect of lack of vitamins; illustrations on the right show individuals from the same broods that have had sufficient vitamins.

Upper—vitamin D; middle, vitamin A; lower, vitamin B.

ultra-violet light rays. These rays are abundant in sunshine and are mostly responsible for sunburn and tan. Investigations have revealed that native South American children who have lived in the open scantily clothed do not suffer from the calcium deficiency which results from too little of vitamin D.

This discovery has made possible the treatment of rickets by the use of arc lamps and mercury vapor lamps which are highly productive of the ultra-violet

rays. Caution should be used in the purchase and use of the so-called sun lamps, as there are many fraudulent products of this sort on the market.

In the use of any sun lamp it is necessary to use great precaution. While ultra-violet rays have been found to be very beneficial, over exposure to them can be very harmful by causing severe and dangerous burns and by reducing the power of the body to fight off bacterial infections.

Vitamin B prevents the disease beri-beri. This vitamin is found in a great many of our common vegetables, such as cabbage, tomatoes, and spinach. It is also abundant in fresh yeast and milk.

Beri-beri is a disease of the nervous system in which the nerves become inflamed. It may result in the rigidity of the muscles.

Exercise. *Health authorities sent to the Philippine Islands following the Spanish-American War found many people ill of beri-beri. An investigation revealed that the diet of many of these people consisted of white or polished rice from which the outside hulls had been removed. It was further found that when these people were fed with rice which contained the outside hulls the victims improved almost at once.*

Exploring expeditions to the Arctic and Antarctic regions in years past have almost always had men afflicted with beri-beri. Their diets were, for the most part, made up from tinned foods and contained no fresh fruits or vegetables. In his two trips to the Antarctic Admiral Byrd did not have a single man ill of beri-beri. Their diet was supplied with vitamins. What inference can one draw from the data presented by these two examples? In your notebook[1] record your inferences.

Vitamin C prevents a skin disease known as scurvy. Have you ever known any person who had this disease? Probably not, because vitamin C is abundant in green vegetables and fruits which are found in the average American diet. Vitamin C is destroyed by prolonged cooking.

Milk which has been boiled or pasteurized contains less of vitamin C, and therefore children fed on milk that has been thus treated must have some substance such as orange juice or tomato juice to supply the needed vitamin. If the proper food is not provided these children may develop scurvy.

Vitamin E prevents sterility. Animals fed on diets lacking vitamin E fail to produce young. It is present in vegetables and especially abundant in grains.

How should we select our food? The amount and kinds of food a person should eat depend upon a number of factors. An individual's activity must be considered. When we indulge in strenuous physical exercise or do hard manual labor, cells in the muscle are used up. We need to eat foods that will build up and repair cells, and for this purpose we need protein foods. Substances containing carbon, oxygen, hydrogen, and nitrogen must be present in the body so that new cells can be made. If you refer to the section on nutrients (page 81) you will recall that proteins are

[1] See workbook, p. 31.

FOODS RICH IN VITAMINS

VITAMIN A	VITAMIN B	VITAMIN C	VITAMIN D	VITAMIN E
Cod-liver oil	Asparagus	Oranges	Cod-liver oil	Seeds of plants, particularly wheat
Cream	Germs of cereal	Lemons	Egg yolk	Leaves of plants, particularly lettuce
Butter	Spinach	Tomatoes	Butter	Lean meat
Whole milk	Brussels sprouts	Rutabagas	Yeast	Milk
Egg yolks	Cabbage	Grapefruit		
Green beans	Tomatoes	Raw cabbage		
Spinach	Carrots	Peas, young, green, raw		
Tomatoes	Peas	Raw carrots		
Carrots	Beans, dried kidney, lima, navy, soy	Raw lettuce		
Yellow corn	Corn and other vegetables if water in which they are cooked is used	Watercress		
Sweet potatoes	Egg yolk	String beans, fresh		
Liver	Oranges	Bananas		
Cheese, whole milk	Lemons	Sweet potatoes		
	Yeast	Raspberries, fresh or canned		
		Strawberries, fresh or canned		
		White turnip		
		Tangerines		

the only food nutrients that contain the element nitrogen.

We must be careful not to eat too much protein, however. We should eat just enough protein food (lean meat, eggs, fish, etc.) for tissue building and eat plenty of carbohydrates and fats to furnish the necessary energy for the body. This is wise for at least two reasons. First, carbohydrates and fats, as a general rule, are less expensive than protein foods. Second, protein foods are more difficult to digest and they produce waste materials which put a strain on the liver and the kidneys.

A mixed diet is best, that is, we should select our foods to include all the nutrients, minerals, vitamins, and water. When our diet contains the proper amounts and proportions of these essentials we say it is *balanced*. It is not possible for us to state here what this balance is for every individual. That depends on height, age, weight, sex, occupation, and climate. Each person must determine for himself what is the proper balance of foods for him. Your weight is one good index of whether your diet is balanced. If you are considerably above normal weight for your age, height, and sex you should eat less of carbohydrates and fats. If you are considerably under normal weight you may not be getting enough of the right kinds of foods or something may be wrong with your body. It is always well to consult a doctor about these matters.

The following simple rules may be used as general guides to healthy eating.

Eat at least twice as much of carbohydrates as of proteins and fats combined.

Eat a mixed diet containing varieties of plant and animal foods to satisfy the normal appetite.

Include liberal amounts of milk, butter, and fresh green vegetables and fruits in your diet.

Eat some food every day that will supply "roughage" in the diet, such as whole wheat bread, bran muffins or cereals, fruits, and coarse vegetables.

Eat sparingly of concentrated foods such as candies and cakes, especially before mealtime.

Drink plenty of water. Many doctors recommend at least six glasses a day. When you drink with your meals do not use the water to dissolve or wash down the food.

Why is milk sometimes called the perfect food? Milk is one of our best and most widely used foods. Figure 125 shows the substances which are present in milk. When milk is "taken apart" it is found to contain the following: carbohydrates in the form of sugar, fats, and proteins in forms easily digested by most persons, and the minerals calcium and phosphorus, both of which are necessary for the building of sound teeth and bones. In addition to these substances milk is rich in vitamins A and B.

Milk is not quite a perfect food because it is deficient in certain minerals, especially iron. It is

ENERGY-GIVING FOODS			BODY BUILDING	BODY BUILDING AND REGULATING FOODS		BODY REGULATING
Starches	Sugars	Fats	Protein	Lime or Calcium	Iron	Roughage
Breads	Sugar	Butter	Milk	American cheese	Greens	String beans
Crackers	Molasses	Cream	Eggs	Milk	Red meat	Cabbage
Macaroni	Sirup	Cheese	Cheese	Buttermilk	String beans	Turnips
Rice	Honey	Lard	Lean meat	Cottage cheese	Dry beans	Squash
Cereals	Preserves	Fat meats	Fish	Egg yolk	Egg yolks	Celery
Cereal products	Jellies	Margarines	Beans	Celery	Bran	Asparagus
Tapioca	Dried fruits	Vegetable and nut oils	Peas	Cauliflower	Cabbage	Lettuce
Potatoes	Candy	Peanut butter	Nuts	Spinach	Whole potatoes	Spinach
Beans	Cake and cookies		Cereals	Cabbage	Asparagus	Onions
Peas	Other desserts			Carrots	Whole cereals	Raisins
				Asparagus	Cabbage	Dates
				String beans	Raisins	Prunes
				Almonds	Dates	Apples
				Dried beans	Figs	Bran
				Whole wheat	Molasses	Whole cereals
				Oatmeal	Prunes	Carrots
					Rhubarb	Beets
					Apricots	Parsnips
					Apples	
					Green beans	
					Almonds	
					Turnips	

also deficient in several vitamins, especially vitamin D. Calcium and phosphorus cannot be utilized properly for the building of bones and teeth unless vitamin D is present. This is one of the reasons some children have bowlegs, deformed chests, or curvature of the spine. In 1927 two noted scientists, Dr. Harry Steenbock and Dr. Alfred Hess, discovered a method of increasing the vitamin D content of foods by means of ultra violet rays. As a result of this famous discovery it is now possible in many communities to buy milk which has been enriched with "sunshine" vitamin D.

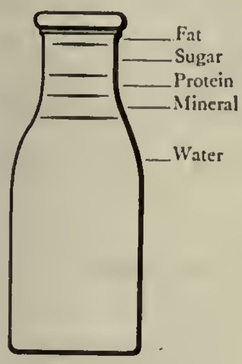

FIG. 125. WHAT A BOTTLE OF MILK CONTAINS

Every person should include milk in his diet. Growing children should consume at least one quart of milk daily.

How can we provide ourselves with pure milk? It is common knowledge that milk sours and curdles readily unless it is kept very cold. Do you know the reason for this? Bacteria thrive well in warm milk. Bacteria that get into milk feed upon the sugar, lactose, and change it into lactic acid. All acids have a sour taste, and this is the reason spoiled milk tastes sour. As the acid increases, it causes the proteins to form lumps or curds, or as we commonly say, the milk curdles. You can demonstrate this fact at home or in the laboratory. Put some fresh milk into a tumbler or a test tube. Add a few drops of dilute hydrochloric acid and observe what happens.

The bacteria that cause milk to sour are not harmful to man, but unfortunately bacteria which produce certain diseases may be present in milk. If a cow has tuberculosis, the bacteria which cause the tuberculosis may get into the milk. A test has been perfected which will reveal the disease if the cow has contracted it. Many states now have regulations which require dairy herds to be tested for tuberculosis at regular intervals. Such cows as show by test that they are afflicted with the disease should be removed from the herd at once.

Epidemics of typhoid fever, diphtheria, and several other diseases have sometimes been traced to the community milk supply. Cows do not have these diseases; therefore, the milk as it is taken from the cow is free of these disease-producing bacteria. The disease bacteria get into the milk through careless handling, frequently from the hands of people who have the disease or from unclean containers in which the milk is placed.

Great care should be taken around the farm to insure clean milk. Stables should be painted or whitewashed. Manure should never be allowed to remain in the barn. All windows should be screened. All containers used to hold milk should be scalded with boiling water. Persons who milk cows should wear clean white clothing and should wash their hands before each milking. The udders of cows should be wiped with a mild disinfectant.

Milk is obtainable in different forms and under different conditions. If it is used directly from the dairy without having been treated in any way it is called raw milk. If raw milk is obtained and handled under guaranteed sanitary conditions it is usually sold under the name of certified milk.


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FIG. 126. SANITARY DAIRY

Since milk is so easily infected with bacteria much of it today is pasteurized before it is distributed to the consumer. The process consists in heating the milk to a temperature of from 142° F. to 150° F. and keeping it at this temperature about thirty minutes and then cooling rapidly. This treatment kills bacteria and safeguards the public from disease germs carried by milk.

REFERENCES FOR FURTHER STUDY

Texts

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Clement, Collister, and Thurston, *Our Surroundings,* Chaps. 26-33

Hunter and Whitman, *My Own Science Problems,* Unit 11; *Science in Our World of Progress,* Unit 15

Lake, Harley, and Welton, *Exploring the World of Science,* Chaps. 26, 27

Pieper and Beauchamp, *Everyday Problems in Science,* Unit 4

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Skilling, *Tours through the World of Science,* Tour 19
Van Buskirk and Smith, *The Science of Everyday Life,* Unit 3
Watkins and Bedell, *General Science for Today,* Unit 11
Webb and Beauchamp, *Science by Observation and Experiment,* Units 4, 7 (parts)
Wood and Carpenter, *Our Environment: How We Use and Control It,* Chap. 18

Special references

Atwood and Heiss, *Educational Biology*
Kinne and Cooley, *Food and Health*
McCollum and Simmonds, *Food, Nutrition, and Health*
Farmers' Bulletins, U. S. Dept. of Agriculture
No. 42. *Good Food Habits For Children*
No. 824. *Foods Rich in Proteins*
No. 808. *What the Body Needs*
No. 1313. *Good Proportions in Diet*
No. 1383. *Food Values and Body Needs*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the food nutrients and their value to the human body.
2. A clear understanding of what is meant by a balanced diet.
3. An understanding of the work and importance of vitamins.
4. A knowledge of the principal food nutrients that are present in our common foods.
5. The value of milk in our diet.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements and comply with the instructions.

1. In order to be able to build up or repair tissues, foods must contain ____.
2. Foods necessary for building bones and teeth must contain ____.
3. The larger percentage of our diet should consist of ____.
4. The element nitrogen is found only in foods containing ____.
5. Organic foods are those contained in ____.
6. Our most nearly perfect food is ____.
7. Leafy vegetables should be eaten because they usually contain ____.
8. Diseases such as scurvy and beri-beri are due to a lack of ____ in the diet.
9. Vitamins are classified by ____.
10. Sugar and starch are known as ____.
11. List five common foods rich in carbohydrates.
12. List four common foods rich in proteins.
13. List five common foods rich in vitamins.
14. List three common foods rich in mineral matter.
15. What work is done by each of the following vitamins: A, B, C, D, E?
16. Starch turns blue in the presence of ____.
17. Benedict's solution is used to test for ____.
18. ____ are used to test for proteins.
19. A positive test for proteins is a ____ color after the addition of ____.
20. It is now possible to treat children for rickets by the use of ____ that produce ____ light rays.
21. One of the food products that has recently appeared on the market in which vitamin D has been produced by irradiation with ultra-violet light is ____.
22. Vitamins are believed by scientists to be built in the ____ leaves of ____.
23. During the war a ship was wrecked on an island where bananas were growing. Many of the crew were suffering from the disease beri-beri. Soon after the men began eating the fresh fruit they improved, and soon the disease was completely eliminated. What inferences can you draw from these data?

TOPIC 3. PREPARING AND PRESERVING FOOD

SUGGESTED PROBLEMS AND QUESTIONS

1. **Why do we cook foods?**
2. **Why do foods spoil?**
3. **What are fungi?**
4. **How may foods be preserved? Study the following methods:**
   Drying
   Salting
   Use of sugar and vinegar
   Sterilization
   Canning
   Refrigeration
5. **What is food adulteration?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully read and study the problems and see if you know anything about them. You should be able to gather considerable information about them by careful observation of the methods employed in your own home for preparing and preserving foods.

2. In connection with problem 2 make a study of bacteria, yeast, and molds. If there is a microscope available in your school look at some bacteria and yeast through it. Molds are easily obtained by keeping some bread exposed in a warm, moist atmosphere. See the experiments suggested in the next section.

3. Consult the references freely in connection with the problems of this topic.

4. You may find the following new words in this study:

fermentation—the production of carbon dioxide and alcohol by the action of bacteria or yeast on sugar.

spore—the reproducing body of plants which have no flowers, such as mosses, ferns, and molds.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 58. What happens to a potato when it is cooked?

Bring two potatoes to class. Pare one of them and cut a thin slice from it. Place it on a glass slide and look at it through a compound microscope. Can you see grains of starch within the cells?

Make a drawing of their appearance in your notebook.

Place a few drops of iodine solution on the freshly pared potato.

What happens?

Pare the second potato. Put it into boiling water and allow it to boil for nearly a half hour. Jab a fork into it occasionally. When it is soft, remove it from the boiling water and examine it carefully. Place a few drops of iodine solution on a slice of the boiled potato and examine it under the microscope.

In your notebook[1] record the notes of this experiment and answer the questions.

How did the boiling water affect the starch grains of the potato?

Was it easier to apply the iodine test after the potato was boiled?

Why do we cook vegetables before eating them?

Experiment 59. What is yeast?

Secure a yeast cake. Place a small part of it in a solution of sugar and water and allow it to stand in a warm room for a short time. By means of a medicine dropper transfer a drop of the yeast solution to a glass slide and examine it under the high power of a compound microscope.

Can you see any of the yeast cells reproducing? How do they reproduce? Record the notes of this experiment in your notebook[2] with a drawing of what you observe. Compare what you observe with Figure 129.

Experiment 60. How do yeast plants affect sugar?

Obtain a flask, a test tube, a one-hole rubber stopper, and some glass tubing. Set up the apparatus as shown in Figure 127. Make a solution of molasses in water, using ten parts of water to one part of molasses. Dissolve about half of a fresh yeast cake in a small quantity of warm water and mix with the solution of molasses. Pour the mixture into the flask. Put limewater into the test tube.[3] In about a half hour examine the apparatus and notice what is happening.

FIG. 127

In your notebook[4] record the notes of this experiment and complete the following statements.

Bubbles of gas formed in the flask. As the bubbles passed through the limewater, the limewater became ____. The name of the gas formed is ____.

As the yeast plants grow they feed upon ____ which is split into ____ and ____.

Why is yeast used in baking bread?

Experiment 61. What are molds and how do they live?

Secure four wide-mouthed glass jars and four slices of bread. Expose the bread to the air for about an hour. Label the jars 1, 2, 3, 4.

a. Moisten one slice of bread, put it in jar 1, cover the jar, and keep it in a warm, dark place.

b. Moisten another slice of bread, put it in jar 2, cover the jar, keep it in strong sunlight.

c. Moisten another slice of bread, put it in jar 3, cover the jar, and keep it in a dark, cold place, preferably a refrigerator.

d. Put the dry piece of bread in jar 4, cover it, and keep it in a warm, dark place.

Notice the changes that appear from day to day on the four slices of bread and keep a record for about a week. Examine the mold with a magnifying glass.

In your notebook[5] record the notes of this experiment and answer the questions.

Does mold grow better in a warm or cold atmosphere? Does mold require water for growth? Does sunlight help or hinder mold in growing? Were different colors present on the bread? What caused them? Under what conditions should food be kept to prevent molding?

Experiment 62. From where do bacteria that cause food to spoil come?

Thoroughly wash a potato and boil it for fifteen minutes. Cut it into thick slices with a knife that has been sterilized in boiling water or a flame. Sterilize several saucers by placing them in boiling water. With the sterilized knife place a slice of potato on a saucer and let it be exposed to the atmosphere for an hour. Cover it with a sterilized glass and keep it in a warm place for a week.

Place another slice of potato on a saucer, rub your fingers over it, cover it with a sterilized glass, and set aside in a warm place.

Watch the development of bacteria colonies for a week. Some molds may also appear. Why?

If a microscope is available, smear some bacteria on a slide and look at them with the high-powered lens. Try to identify different kinds of bacteria.

In your notebook[6] record your observations and results, make drawings, answer the questions, and complete the statements.

Are bacteria in the air? Are bacteria on our hands? What happens to bacteria when dishes are boiled in water? What causes milk to sour?

Bacteria are classified according to their shape. What are rod-shaped forms called? Spherical-shaped forms? Spiral-shaped forms?

[1] See workbook, p. 31.
[2] See workbook, p. 32.
[3] See directions for making limewater, footnote, p. 62.
[4] See workbook, p. 32.
[5] See workbook, p. 33.
[6] See workbook, p. 33.

OTHER INVESTIGATIONS WHICH YOU CAN CARRY ON

1. Make a survey of the stores in your community to see whether foods are kept and sold under sanitary conditions. Report your findings to the class.
2. Investigate the life and achievements of Louis Pasteur.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Why do we cook foods? It is quite likely that primitive man lived almost entirely on uncooked foods. Today we consume most of our foods only after they are cooked.

Foods are cooked for at least three reasons. First, cooking improves the flavor or makes food taste better, as we more commonly say. Most of us do not enjoy raw meat and raw vegetables, but, by cooking and seasoning, these same substances may be transformed into appetizing dishes. Second, cooking makes most foods more digestible. The action of heat on foods softens the tough fibers of meats and breaks the cell walls around the starch in starchy foods. If you have performed the experiment of cooking a potato, mentioned at the beginning of the topic, you will recall how this takes place. This is an aid to digestion because the digestive juices are able to act more readily on the food nutrients. Third, cooking foods kills any disease-producing organisms they may contain. Bacteria, molds, worms—in fact, all living things that contaminate food and cause human diseases—are killed by the heat of boiling water. Therefore it is safer to eat cooked foods.

Not all foods react in the same way to the action of heat. Some foods may be less palatable and more difficult to digest when cooked the wrong way than if

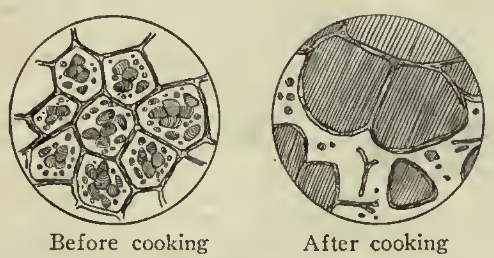


FIG. 128. STARCH CELLS

they had not been cooked at all. Cooking requires careful study and practice if one wishes to become proficient at it.

There are five common methods of cooking, and by each method it is the action of heat that does the cooking. Each method is simply a different way of applying the heat to the foods. The five methods are *boiling,* in which foods are cooked in boiling water or in water just below the boiling point as in stewing; *broiling,* in which foods are cooked directly over the source of heat; *steaming,* in which the foods are cooked in the steam from boiling water; *frying,* in which the foods are cooked in hot fats; *baking and roasting,* in which the food is placed in a container in a heated oven or over a fire.

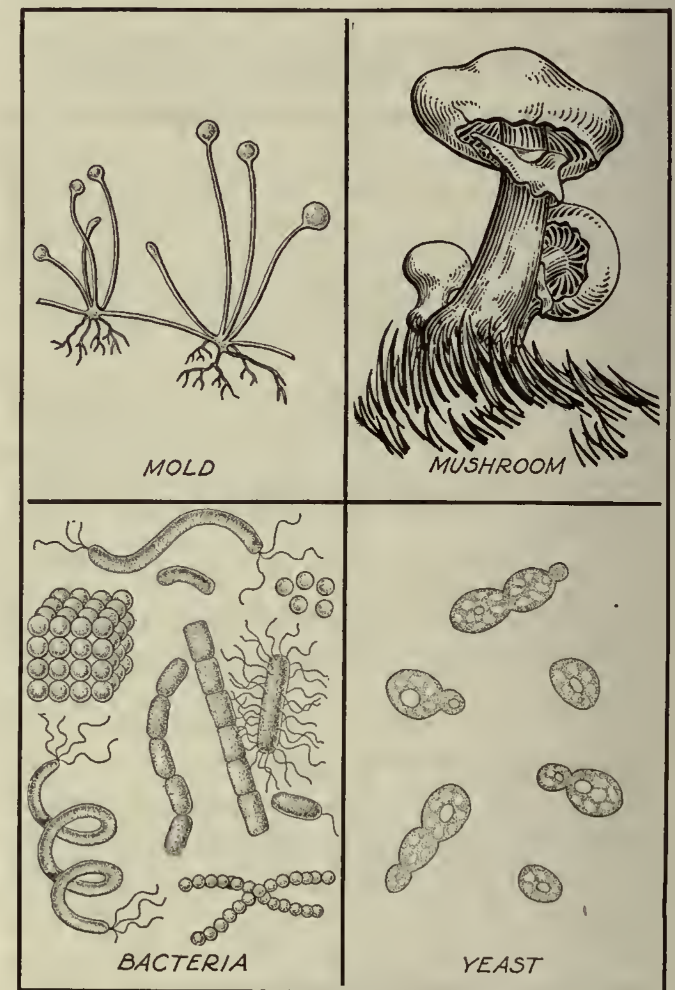


FIG. 129. FUNGI

Fruits and vegetables are frequently sprayed or coated with poisonous substances while growing to prevent the ravages of certain insect pests. Often these poisons remain on the fruits or vegetables until they have reached the consumer. It is therefore always wise to wash thoroughly all such foodstuffs before they are eaten, cooked, or placed in a refrigerator for storage. In the case of fruits and some vegetables, the outer peel or leaves are removed. It is, however, best to wash these foods also.

Why do foods spoil? We learned in a previous topic that green plants with the aid of sunlight make food out of inorganic matter. There exists, however, a group of plants comprising more than one-fourth of all the plants in the world that do not have chlorophyll in them and therefore cannot manufacture food.

These plants are called *fungi* (fun′ji). Like every other form of life these fungi must have food, and we find them wherever there is a food supply and wherever their surroundings permit growth.

When plants and animals die, the food of their bodies is used by fungi. Did you ever wonder what becomes of all the dead leaves, logs, and branches of trees when they die in the woods? Fungi cause them to decay, and eventually the organic material is changed back into inorganic material and goes back to the soil and to the air. On the other hand, meats, fruits, vegetables, and other foodstuffs are attacked by fungi and used for their food, thus becoming unfit for our use. It is a constant struggle for man to keep food in a state of preservation until he is ready to use it.

What are fungi? There are four general types of fungi, but only three of them are of importance in destroying our food. They are *molds, yeast,* and *bacteria.*

Have you ever examined a piece of moldy bread? Most of us are familiar with the musty odor which comes from things on which molds are growing. There are many varieties of molds. If you examine them under a strong magnifying glass you will see that they bear spore cups which contain many *spores.* These may be black, yellow, blue, or green. Each of these tiny spores is capable of growing into a new mold plant when it comes in contact with warm, moist food.

Bacteria are tiny one-celled plants which live on either dead or living material. Like molds, they destroy the things on which they grow. If they grow in food, they spoil it, yet strangely enough their presence is desirable in making a few foods such as sauerkraut and some kinds of cheese. Thus bacteria may be beneficial or harmful. If they grow on dead leaves and dead animals and change the dead organic material to soil, we consider them very useful. Those which cause foods to spoil or cause diseases are classified as harmful types.

Bacteria seem to be everywhere. Many of them form spores, although not in the same way as molds. These spores are carried around in the air. We eat them with our foods; we drink them and breathe them by the millions. Most of them do us no harm. Those which cause disease we shall study in a later unit.

Yeasts are also small single-celled plants, microscopic in size. They are somewhat larger, however, than most bacteria and are found in fruit juices or where sugar is fermenting. These organisms use sugar for food and change it to carbon dioxide and alcohol. This process is known as fermentation. It is used in bread making to produce carbon dioxide, which makes the dough rise, and in distilling industries to produce alcohol.

Yeasts reproduce by a process called budding. Little "buds" grow out from the end of the cell and finally get to be as large as the parent cell. Yeasts also reproduce by spores which are carried around as dust in the air. Like mold and bacteria spores they may fall on certain foods and cause them to spoil.

How may foods be preserved? Drying was one of the first methods ever used to preserve food. Bacteria, yeast, and molds cannot grow where there is no moisture. This method of food preservation was in use thousands of years ago and is practiced today. Meats, fish, and different fruits such as apples, peaches, prunes, and raisins are preserved by this method.

International News Photos, Inc.

FIG. 130. FIG DRYING

Salting is another old method used to preserve food. Bacteria and other fungi are unable to live in a strong salt solution.

Many other chemicals, called *preservatives,* prevent the growth of fungi in foods. Sugar, when used in a concentrated form, is a good preservative. Fruits are sometimes preserved by boiling them in sugar syrup. Fruits may also be dried and then "sugared." Certain acids destroy or prevent bacterial growth. Vinegar (acetic acid) is perhaps the most widely used acid preservative. Benzoic and salicylic acids destroy fungi, but there is some question as to the advisability of their use in foods. They may be slightly harmful to some people.

Canning has been found to be one of the most satisfactory methods to prevent foods from spoiling. The common method consists of sterilizing the food and the cans by boiling them in water. The action of the heat kills bacteria and spores. The food is then put into the cans and sealed with can tops that have also been sterilized. In recent years the *cold pack* method of canning has come into use. The process consists of putting the cold, uncooked fruit or vegetables into jars or cans and sealing them. The cans are then heated in boiling water or a pressure cooker until all bacteria or spores are killed.

Refrigeration. Bacteria do not grow and multiply at low temperatures. For this reason refrigerators have come into general use as a method of preventing the spoiling of food. Refrigeration should not be confused with sterilization, however, as a cold temperature does not kill bacteria—it simply prevents their growth. If water or food is impure, freezing will not purify it. The temperature within a refrigerator should never be above 50° F. to keep foods from spoiling.

In Unit II, Topic 1, problem 4, pages 31-32, you learned how cold was produced by evaporation in the electric refrigerator and cold-storage plant. Review that problem at this time and be sure that you understand the construction and operation of these modern refrigerating devices.

In the ice refrigerator the low temperature is produced by melting ice. The box is well insulated to keep outside heat from entering. Thus any heat that is secured to melt the ice must come from the materials inside the box. This chills them and prevents the growth of bacteria.

Since cold air is heavier than warm air, convection currents are set up inside the box which keep the air

Ruth Cunliff Russell

FIG. 131. REFRIGERATED MARKET

circulating continually. The air near the ice becomes chilled, starts to fall toward the lower portion of the box, and pushes the warm air toward the top.

Exercise. *Is the temperature the same in all parts of a refrigerator? Devise a method of testing this problem and, after investigating, record the results in your notebook. Suggest where meat and milk, both of which must be kept very cold, should be placed in a refrigerator to secure the lowest temperatures.*

In recent years another substance known as "dry ice" has come into common use for refrigerating ice cream and other foods. Dry ice is solid carbon dioxide. It is made by compressing the gas carbon dioxide and then letting it expand. The expansion removes sufficient heat to solidify the gas. Since dry ice is about 140 degrees Fahrenheit colder than ordinary ice, a much smaller quantity is needed for cooling.

What is food adulteration? In 1906 the Congress of the United States passed what is commonly known as the Pure Food and Drug Act. The purpose of this law was to protect the consumer of prepared foods from fraudulent practices in their preparation and preservation. Foods may be adulterated in any of the following ways:

Substances may be added to cheapen the food.

Substances may be mixed with a foodstuff to reduce or change its quality.

Valuable parts may be removed from a foodstuff.

Coloring matter may be added to conceal damaged or inferior materials.

Poisonous materials may be added for purposes of preservation.

Vegetable or animal substances may be used which are regarded as unfit to eat.

Exercise. *Study the labels on canned foods and see how many you are able to collect that would illustrate any of these ways of adulterating foods. Suggest foods that may be adulterated in other ways. Paste in your notebook any labels you may find and write out the suggestions of foods that may be adulterated in the other ways mentioned above.*

The Pure Food and Drug Act prohibits the use of certain substances in prepared foods and requires that, when certain others are used, this fact be clearly printed on the container. In this respect the law has been beneficial. Since 1906, however, many new substances have come into use, some of which are more harmful than those specified by the law.

This act provides only for those foods that are sold from one state to another. Adulteration of foods manufactured and sold locally is possible unless state and city laws prevent and unless authorities in these places are exceedingly alert. Thus it is quite evident that our pure food laws are somewhat out of date and in need of some revision that will better protect from injurious adulterants those persons who depend on prepared foods.

Of course, not all adulterants are harmful. Corn sirup is frequently used as an adulterant in maple sirup or honey. Oleomargerine is sold as a substitute for butter. Neither of these substances is harmful; they are, in fact, wholesome foods. Because these substances are cheaper than the foods for which they are substituted, they are regarded as adulterants according to the Pure Food and Drug Act of 1906.

If their use is stated on the container label, some questionable substances are permitted as preservatives by the Pure Food and Drug Act. Among these substances are benzoic acid, sodium benzoate, borax, alum, and others. Certain fruits are bleached and others are dyed with harmful chemical substances. These practices are not in the interest of the good health of the consumer, even though they may be within the law.

Exercise. *Write in your notebook*[1] *a summary of your ideas regarding pure foods and the protection of the consumer.*

FEDERAL FOOD & DRUGS ACT

HERE ARE ITS POWERS AND LIMITATIONS REGARDING THE SALE OF "PATENT MEDICINES"

IT APPLIES ONLY TO PRODUCTS THAT ARE MADE IN ONE STATE AND SOLD IN ANOTHER (INTERSTATE COMMERCE).

IT PROHIBITS "FALSE OR MISLEADING" STATEMENTS (IN OR ON THE TRADE PACKAGE ONLY) REGARDING COMPOSITION AND SOURCE OF ORIGIN.

IT PROHIBITS "FALSE AND FRAUDULENT" STATEMENTS (IN OR ON THE TRADE PACKAGE ONLY) REGARDING CURATIVE EFFECTS.

IT REQUIRES THE MANUFACTURERS OF NOSTRUMS TO DECLARE (IN OR ON THE TRADE PACKAGE ONLY) THE PRESENCE AND AMOUNT OF ALCOHOL, MORPHIN, OPIUM, COCAIN, HEROIN, EUCAIN, CHLOROFORM, CANNABIS INDICA, CHLORAL HYDRATE AND ACETANILID AND THEIR DERIVATIVES.

IT DOES NOT APPLY TO PRODUCTS THAT ARE SOLD IN THE SAME STATE AS THAT IN WHICH THEY ARE MADE (INTRA-STATE COMMERCE).

IT DOES NOT PROHIBIT FALSE OR MISLEADING STATEMENTS IN NEWSPAPER ADVERTISEMENTS, CIRCULARS, WINDOW DISPLAYS, ETC.

IT DOES NOT PROHIBIT ANY KIND OF A LIE REGARDING CURATIVE EFFECTS IF THAT LIE IS TOLD ELSEWHERE THAN IN OR ON THE TRADE PACKAGE!

IT DOES NOT REQUIRE "PATENT MEDICINE" MAKERS TO DECLARE EVEN THE PRESENCE OF SUCH DEADLY POISONS AS PRUSSIC ACID, CARBOLIC ACID, ARSENIC, STRYCHNIN—NOR ANY OF SCORES OF OTHER DANGEROUS DRUGS!

Courtesy American Medical Association

FIG. 132. FACTS CONCERNING THE FEDERAL FOOD AND DRUG ACT OF 1906

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 35
Clement, Collister, and Thurston, *Our Surroundings*, Chaps. 26-33
Hunter and Whitman, *My Own Science Problems*, Unit 11; *Science in Our World of Progress*, Unit 15
Lake, Harley, and Welton, *Exploring the World of Science*, Chaps. 26, 27
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 4
Powers, Neuner, and Bruner, *The World around Us*, Chap. 22; *This Changing World*, Unit 6; *Man's Control of His Environment*, Chap. 28
Skilling, *Tours through the World of Science*, Chap. 28
Van Buskirk and Smith, *The Science of Everyday Life*, Unit 3
Watkins and Bedell, *General Science for Today*, Unit 11
Webb and Beauchamp, *Science by Observation and Experiment*, Units 4, 8 (parts)
Wood and Carpenter, *Our Environment: How We Use and Control It*, Chap. 18

Special references

Atwood and Heiss, *Educational Biology*
Conn, *Bacteria, Yeasts, and Molds in the Home*
Morris, *Household Science and Arts*
Prudden, *The Story of Bacteria*
Farmers' Bulletins, United States Department of Agriculture
No. 34. *Meats: Composition and Cooking*
No. 363. *The Use of Milk as Food*

[1] See workbook, p. 34.

No. 375. *The Care of Food in the Home*
No. 413. *Care of Milk and Use in the Home*
No. 841. *Drying Fruits and Vegetables in the Home*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The values of cooking food.
2. An understanding of the conditions which cause food to spoil.
3. A knowledge of the various methods used to preserve food.
4. A knowledge of how foods are adulterated and how adulteration affects the consumer.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. State three reasons for cooking food.
2. Heating milk at a temperature of about ____ for a period of thirty minutes and then cooling it is called ____.
3. What is the most satisfactory method of safeguarding milk from disease germs?
4. State five methods used to preserve foods.
5. Three plant organisms that cause food to spoil are ____.
6. Milk is caused to sour by ____.
7. Drying keeps some foods from spoiling because bacteria need ____.
8. Heat will ____ bacteria.
9. Sunlight will ____ bacteria.
10. Canning makes use of the fact that bacteria are ____ by ____.
11. Milk is an excellent food because it ____.
12. The temperature in a refrigerator should be below ____ degrees Fahrenheit.
13. What are the three types of bacteria?
14. Ice in a refrigerator may be kept from melting by wrapping it in newspaper. What do you think of this in regard to the effective preservation of food in a refrigerator?
15. Dry ice is ____. It is prepared by letting ____ expand. This ____ heat and therefore the ____ turns to a ____ state because its temperature is ____.
16. Dry ice is ____ degrees colder than ordinary ice.
17. Tell how you believe the Pure Food and Drug Act could be improved.

TOPIC 4. HOW THE HUMAN BODY USES FOOD

SUGGESTED PROBLEMS AND QUESTIONS

1. **How is our food digested?**
2. **How is digested food absorbed?**
3. **How is food circulated in the body?**
   a. **How is blood forced through the body?**
   b. **Of what is blood composed?**
   c. **What are the functions of arteries, veins, and capillaries?**
4. **How is energy released to the body?**

SUGGESTIONS AND HELPS FOR STUDY

1. You can obtain from this and other general science textbooks all the information that you need to solve the problems above.
2. Keep in mind when you are studying the digestive, circulatory, and respiratory systems that they all work together to keep our bodies well nourished and to release a sufficient amount of energy.
3. As you read your textbook be sure to examine and study very carefully the pictures and drawings of the organs which make up the various systems that you are studying.
4. The following words may be new and difficult for you. Study them carefully and use them often.

gland—an organ which makes a special kind of body fluid; *e.g.*, the salivary glands in the mouth, which make saliva.
corpuscle—a small body in the blood. There are red and white corpuscles.
haemoglobin—the red protein in the red corpuscles.
assimilate—to take in.
artery—a blood vessel which conveys blood from the heart.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 63. What does saliva do to starch?

Boil a small amount of starch in a test tube. Add some saliva to the starch, shake it well, and let it stand thirty minutes. Add Benedict's solution and heat. As a check on the experiment add Benedict's solution to some boiled starch in a test tube to which no saliva has been added, and heat.

If you have time, repeat the experiment, using unsweetened cracker in place of starch. What happened?

In your notebook[1] complete the following statements and answer the question.

Benedict's solution is used to test for ____. In the test tube containing starch and saliva, the color of the Benedict's solution changed to ____. This showed that saliva changes starch to ____.

Experiment 64. What digestion takes place in the stomach?

Obtain some pepsin at your local drug store or from a dealer in biological supplies. Mince the white of a boiled egg very fine. Place small quantities of the egg in four test tubes. Label the tubes A, B, C, D. In test tube A, add some pepsin solution and mix thoroughly. In test tube B, add some pepsin solution and about two drops of sodium hydroxide solution and mix thoroughly. In test tube C, add some pepsin solution and one drop of dilute hydrochloric acid. Mix well. In test tube D, add pepsin solution and several drops of dilute hydrochloric acid. Mix well.

Allow the four test tubes to stand in a warm place for

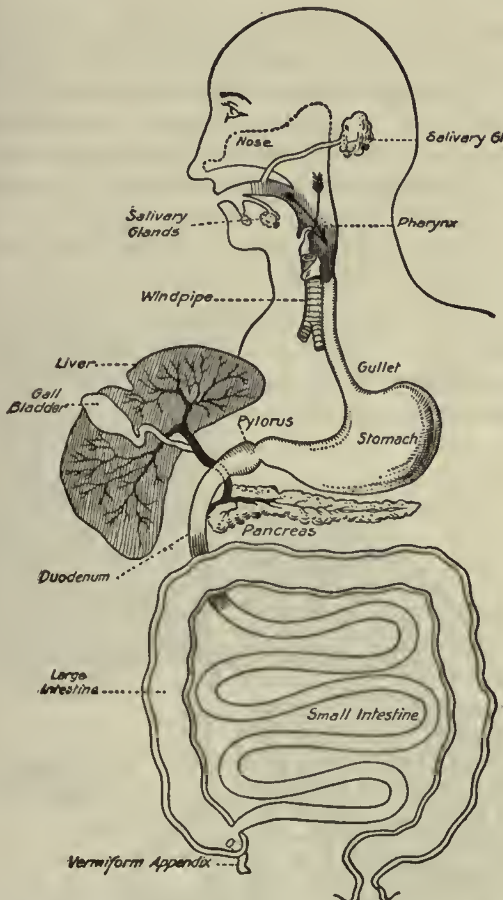
[1] See workbook, p. 34.

about two days. Examine the contents of each tube. Did digestion take place in tube A? In B? In C? In D? By what two agents are proteins digested in the stomach?

Record the notes of this experiment in your notebook.[1]

Experiment 65. Is your heart a pump?

Practice counting the beat of your pulse. Find the pulse on the inside of your left wrist by placing the first finger of your right hand across it. The pulse beat is caused by the pumping of blood through the arteries by the heart.



Courtesy P. Blakiston's Son

FIG. 133. DIGESTIVE SYSTEM

Using the second hand of a watch, practice counting the number of heart beats per minute. How many times does your heart beat a minute while you are standing up?

Exercise vigorously for several minutes. What is the number of heart beats per minute just after exercising?

Count the number of times you breathe a minute before exercising. Count the number of times you breathe a minute after vigorous exercise. Is there any relation between breathing and heart action?

In your notebook[2] record the notes of this experiment and answer the questions.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Learn how to apply artificial respiration.

2. Make a study of patent medicines and their effect on the human body. Collect clippings about them from newspapers and magazines.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Most of the foods we eat cannot be used by our bodies in their natural form because they are not soluble. The foods will not dissolve, hence the human body is not able to absorb and assimilate[3] them. The process by which our bodies change foods into a soluble form so that they can be absorbed by the body cells is called *digestion.*

How is our food digested? Food is taken into the mouth, chewed, and then swallowed. It then passes through the gullet to the stomach. From the stomach it passes through the small intestines, then through the large intestine. During this time the food is mixed with various digestive juices which change insoluble substances to soluble forms. See Figure 133.

In the mouth the food is ground fine and mixed with saliva secreted by three pairs of salivary glands. Substances in the saliva change some of the starch in the foods to sugar. By the act of swallowing, the food passes into the gullet, a long tube that connects the mouth with the stomach.

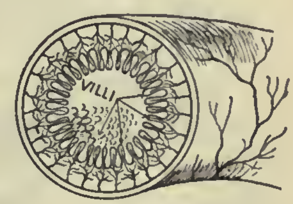


FIG. 134. CROSS SECTION OF INTESTINE

In the walls of the stomach are small glands that secrete *gastric juice.* Through the action of muscles in the walls of the stomach the food is thoroughly mixed with the gastric juice. The digestion of starch stops, while the materials in the gastric juice begin the digestion of proteins in the food. At intervals portions of the partly digested food are forced out of the stomach into the small intestine.

In the small intestine the food is mixed with *bile* from the liver, *pancreatic juice* from the pancreas, and *intestinal* juices secreted from the walls of the intestine. These digestive juices complete the process of digestion. The starch and proteins are further acted upon and the fats are also digested. All undigested materials pass into the large intestine and are expelled from the body as waste matter.

How can we keep our digestive system in good working order? Retaining food in the mouth and chewing it well is beneficial to digestion. Small pieces of food particles are more easily acted upon by the

[1] See workbook, p. 34.

[2] See workbook, p. 34.

[3] *Assimilate,* to convert nourishing material into the fluid or solid substance of the body. It is the last stage in the process of nutrition, following after digestion.

digestive juices than are larger pieces. It is essential, therefore, that a clean mouth and sound teeth be maintained.

Proper diet is an important factor in building up and maintaining sound teeth. The *enamel,* the hard, outer structure of teeth, is formed largely from calcium and phosphorus. Certain vitamins, especially vitamin D, must be present in our diet, in order that the body can utilize minerals in building teeth. If liberal amounts of fruit, leafy vegetables, and milk are included in the daily diet and if our bodies receive a reasonable amount of exposure to sunshine, all the essential elements for the building of sound teeth will be provided.

Teeth are subject to decay, but they do not repair themselves. Every person should visit a dentist at

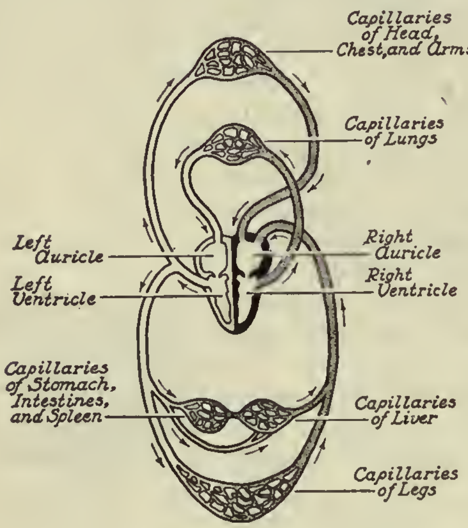


FIG. 135. CIRCULATORY SYSTEM OF MAN

least once a year. The mouth should be inspected for the beginning of tooth cavities and diseases of the gums. The teeth should be cleaned and repaired if necessary. It is poor economy to delay having the teeth repaired until they are badly damaged. One should not bite hard objects with the teeth. Cracking nuts, biting very hard candy, or biting string may crack the enamel. Pins and needles should not be used to pick the teeth. Why?

The following factors may influence digestion:

Poor posture, which cramps the digestive organs and which may prevent good circulation of blood through them.

Fatigue. Undue fatigue may prevent satisfactory digestion. When "too tired to eat," rest a while before eating a full meal.

Lack of exercise is one of the causes of a poor appetite. Lack of exercise may also result in poor circulation. Daily moderate exercise tends to stimulate the appetite and also to "tone up" the digestive system. It is not considered wise, however to indulge in strenuous exercise immediately after a heavy meal.

Emotional state. Pleasant emotions increase the appetite and aid the flow of digestive juices. Worry, anger, and fear retard the digestive processes and in extreme cases may even cause digestion to cease. One should form the habit of being cheerful at meal time. Avoid quarreling and talking over your troubles while eating. Make breakfast, lunch, and dinner happy occasions.

Constipation. Improper eating may cause constipation. Usually waste matter is eliminated from the intestines once every twenty-four hours. If waste materials are held in the body too long, they may irritate the intestinal tract and cause pain and symptoms of indigestion. Constipation may also produce headache or make one feel sluggish and drowsy.

Medicines are available for the relief of constipation, but it is better to aid the bowels to do their work themselves. The following things are suggested to accomplish this purpose. Daily outdoor exercise seems to increase the vitality of all the cells. Exercises which strengthen the abdominal muscles are helpful.

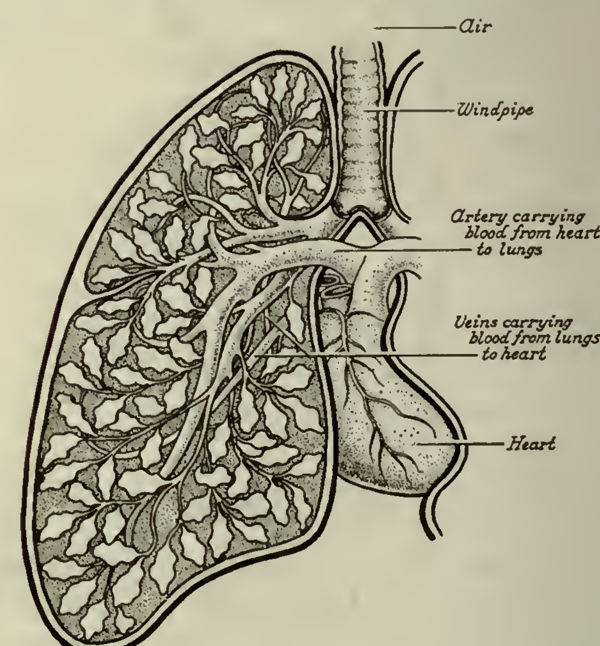


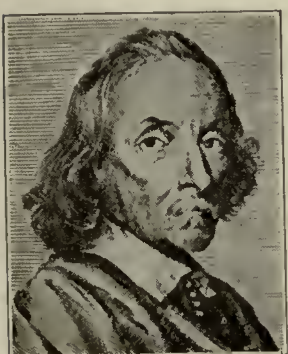
FIG. 136. LUNG OF MAN

Persons who have poor posture and weak abdominal muscles which result in sagging intestines frequently suffer from constipation. Drinking more water, especially before retiring at night and after arising in the morning, and eating more fruit, vegetables, and coarse foods such as bran muffins and bran bread which supply plenty of roughage bring relief in most cases. In case of persistent constipation it is best to consult a physician.

How is digested food absorbed? Absorption of the digested food takes place almost entirely through the walls of the small intestine by osmosis of the soluble foods. The intestines are well adapted for this purpose. In an adult they are about twenty feet long, and the inner surface is greatly increased by a succession of circular ridges and depressions, and by millions of finger-like projections which extend into the interior of the intestines. These projections, known as *villi* (*sing.*, *villus*) are lined with networks of fine blood vessels into which the digested food passes as it is absorbed by the villi. See Figure 134.

How is food circulated in the body? After food has been digested and absorbed it must be distributed to all parts of the body where the cells use it. The cells of the muscles, bones, nerves, glands, etc., must all receive nourishment.

The distribution of the food is carried on by our circulatory system (see Figure 135). The heart pumps blood to all parts of the body through blood vessels known as *arteries*. The main arteries branch first into the smaller arteries and then into tiny blood vessels called *capillaries* which extend to practically every part of the body. You know this to be true, for if you prick or cut yourself almost anywhere on the surface of your body, blood will appear. The cells of the body, which are in close contact with the capillaries, receive the food from the blood in them. The blood in turn takes on waste materials from the cells. The capillaries join to form small *veins*. The smaller veins form larger veins which lead back to the heart.

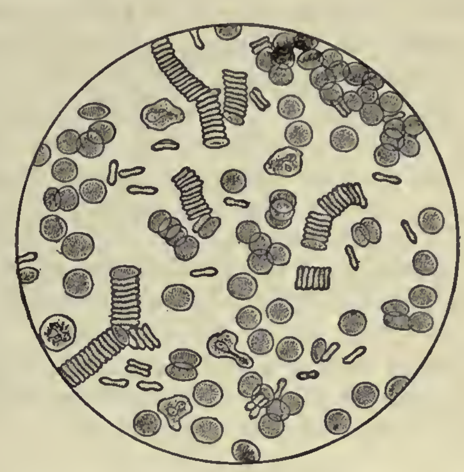


Science Service

FIG. 137. WILLIAM HARVEY
His discovery of the process of blood circulation is one of the early great achievements of modern experimental science.

This wonderful process of circulation was discovered by William Harvey, an English physician, about three hundred years ago. It is one of the greatest discoveries ever made in science, and yet when Harvey first announced his discovery most people did not believe him; in fact, he was ridiculed by many. Do you think that it is scientific to resist the introduction of new knowledge?

Blood is composed of a liquid called *plasma* in which are located red and white corpuscles. The red corpuscles give the blood its color as they are more numerous than the white ones. Their chief constituent is a complex substance called *haemoglobin* which carries oxygen to the cells of the body. The white corpuscles aid the body in resisting disease germs. They engulf bacteria that enter the blood and assemble in places where infection occurs to help the body resist the invasion of germs.



Courtesy P. Blakiston's Son

FIG. 138. WHITE AND RED CORPUSCLES UNDER THE MICROSCOPE

When the human body is cut, blood flows from the wound. If only the capillaries are severed, the blood escapes slowly. If the cut is deep and arteries or veins are severed, blood flows rapidly. Blood from veins flows steadily and is darker in color than blood from arteries. Blood from arteries pulsates, because of the pumping action of the heart. Blood contains a substance which thickens when exposed to the air. This causes blood to clot and prevents us from bleeding to death. When an artery is cut, the blood may not clot rapidly enough to stop bleeding. When this happens a cloth tied tightly near the cut, on the side nearer the heart, may slow the flow of blood sufficiently to allow it to clot. The cloth tied near the wound should be loosened again after about ten minutes or serious complications may develop.

FIG. 139
TOURNIQUET

How is energy released to the body? Energy is released to the body by oxidation. This takes place in every cell of the body. Oxidation is made possible through breathing. Breathing refers to the process of taking air into the lungs and expelling the waste products. In the lungs, oxygen is taken up by the blood and carried to all the cells of the body, where oxidation takes place, forming carbon dioxide, which is returned to the lungs by the blood. The carbon dioxide is thrown off as a waste product through

breathing. The exchange of gases between cells of the body and the air is called *respiration*, and breathing is a part of the process.

Summary. We have seen in the study of this topic that the human body obtains energy by oxidation. It is the fundamental purpose of digestion to prepare foods so that they can be absorbed by the body. It is the fundamental purpose of circulation to distribute the absorbed food and oxygen to the cells of the body and to carry waste products to the excretory organs such as the lungs and kidneys. It is the fundamental purpose of respiration to furnish oxygen for oxidation and to help eliminate waste products formed during the process. Thus we see that the digestive system, the circulatory system, and the respiratory system all work together to keep our bodies well nourished and to furnish them with sufficient energy.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 35
Clement, Collister, and Thurston, *Our Surroundings*, Chaps. 26-33
Hunter and Whitman, *My Own Science Problems*, Unit 11; *Science in Our World of Progress*, Unit 15
Lake, Harley, and Welton, *Exploring the World of Science*, Chaps. 26, 27
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 4
Powers, Neuner, and Bruner, *The World around Us*, Chap. 22; *This Changing World*, Unit 6; *Man's Control of His Environment*, Chap. 28
Skilling, *Tours through the World of Science*, Tour 19
Van Buskirk and Smith, *The Science of Everyday Life*, Unit 3
Watkins and Bedell, *General Science for Today*, Unit 11
Webb and Beauchamp, *Science by Observation and Experiment*, Units 4, 8 (parts)
Wood and Carpenter, *Our Environment: Its Relation to Us*, Unit 8; *Our Environment: How We Use and Control It*, Chaps. 19, 20

Special references

Atwood and Heiss, *Educational Biology*
Jewett, *Good Health*
Ritchie, *Primer of Sanitation*
Broadhurst, *Home and Community Hygiene*
Hough and Sedgwick, *The Human Mechanism*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of how our digestive system works.
2. A knowledge of how our circulatory system works.
3. A knowledge of how our respiratory system works.

TEST OF MASTERY OF THE TOPIC

Complete the statements in your notebook.

1. Digestion of food is necessary so that the food can be ——.
2. Digestion of starch begins in the ——.
3. The digestive juice secreted in the mouth is called ——.
4. The digestive juice secreted in the stomach is called ——.
5. The process of changing solid food to —— form in the body is called ——.
6. Absorption of digested food takes place mostly in the ——.
7. Tubes that carry pure blood away from the heart are called ——.
8. Impure blood is purified principally in the ——.
9. The circulation of blood through the body is caused by the ——.
10. Oxygen enters the blood in the ——.
11. One should always breathe through the ——.
12. Digestion is completed in the ——.
13. Blood is forced throughout the body by the pump action of the ——. Pure blood passes from the heart first into the ——, then into ——, then into —— which carry it back to the heart. The impure blood is then pumped to the ——, to be ——.
14. Oxygen is carried to all parts of the body by —— in the blood.
15. To stop the flow of blood from an artery, tie a piece of cloth or cord between the —— and the ——.
16. The air we breathe out contains more —— and ——, and less —— than the air we breathe in.

SUPPLEMENTARY MATERIALS

Reading suggestions

De Kruif, *Hunger Fighters* (Harcourt)
Carpenter, *How The World Is Fed* (American Book)
Broadhurst, *Home and Community Hygiene* (Lippincott)
Fisher and Fisk, *How To Live* (Funk)
Harris, Lacey, and Blood, *Everyday Foods* (Houghton)
Rose, *Feeding the Family* (Macmillan)
Prudden, *Dust and Its Dangers* (Putnam)
Carpenter, *Foods and Their Uses* (Scribner)
Hartley and Leyel, *Lucullus* (Dutton)
Meredith, *The Health of Youth* (Blakiston)
Johnson, *Bacteriology of the Home* (Manual Arts)
Worthington and Matthews, *Our Food* (Owen)
MacDougal, *The Green Leaf* (Appleton)
Heaton, *The Human Body* (Dutton)

Reports which may be prepared

1. Recent discoveries about vitamins
2. The life and work of Louis Pasteur
3. Your town's regulations for care of milk supply
4. Common diseases spread by milk and water
5. How bread is made

6. The dangers from flies in the home
7. The pure food laws of my state
8. The sources of the foods I eat
9. The value and costs of foods used in the home
10. Laws protecting my community's food supply
11. Harmful effects of alcohol on the human body
12. The production and marketing of foods
13. Foods of other lands
14. The story of sugar
15. Modern methods of preserving foods
16. Frozen foods
17. Foods of the future
18. The production and marketing of milk

Great scientists you should know about

1. Luther Burbank
2. Louis Pasteur

Investigations and things to do

1. Visit the food stores of your community and inspect them. Rate them on the basis of the following: neatness, presence of flies and other insects, whether food is covered or not, cleanliness of the employees.

2. Learn how to test for proteins, carbohydrates, fats, and mineral matter in foods. Apply these tests to some common foods.

3. Visit a cold storage plant.

4. Report on the dairies that supply your milk.

5. Prepare a balanced menu for a week's meals.

6. Visit the health department of your community and inquire as to methods of food inspection.

7. Visit a dairy and see how the milk is pasteurized.

8. Make a collection of labels of patent medicines, and make a study of the alcohol content in them.

UNIT V. HOW WE LIGHT OUR HOMES

The brilliant illumination found today in our homes, public buildings, and city streets has been made possible through recent rapid advances in the fields of science and invention. The great improvement from the smoky pine torch and candles of early times to the brilliance of our present day electric lamp is a remarkable example of the progress of science and invention. Early dwellers on the earth had no other light than that received from the sun during the day and the moon and stars by night. The darkness was feared and man's activity practically ceased at sunset.

The bonfire was probably the first form of artificial light used by early man, but when and how he learned to use it we shall probably never know. Next came the development of the pine torch, by means of which our ancestors were able to leave their dwelling places at night. The use of the pine torch persisted for many centuries, but as civilization progressed various new devices were tried. Dried rushes boiled in grease from cooked meats were used for a while and were soon followed by bowls of grease in which some form of wick was placed. Then the candle, made from solid fats and waxes, was invented, its efficiency being so much greater than that of any of the preceding devices that it remained the chief source of artificial light for centuries. The candle was eventually replaced by the kerosene lamp, which has since been replaced by our modern gas and electric lights.

The invention of window glass, about four hundred years ago, combined with our modern gas and electric lighting systems, has made our homes cheery places in which to live both by day and by night. During the Middle Ages the castles of the wealthy noblemen were just as dark and damp as the tiny huts of the peasants, for there was no way of letting in the light and at the same time keeping out the cold.

In this unit you will learn some of the fundamental principles of light, the methods of producing artificial light, and principles of control of the illumination in your homes in a hygienic way. You will also learn about devices which make use of light, such as the human eye and the camera.

How many of these questions about light can you answer? Write the answers in your notebook under the proper heading.

1. What is light?
2. How does light from the sun reach the earth?
3. How many devices for producing artificial light have you in your own home?
4. Which do you find the more cheerful in your home, rooms with light-colored walls or rooms with dark-colored walls? Why?
5. What causes an electric-light bulb to give light?
6. What are the colors of a rainbow? What causes a rainbow?
7. Name ways by which we derive benefit from light.
8. Why are you able to see yourself in a mirror?
9. Why is the flame of a lighted candle yellow?
10. Who invented the incandescent bulb?

TOPIC 1. THE HISTORY OF LIGHTING

SUGGESTED PROBLEMS AND QUESTIONS

1. **How did people of olden times light their homes?**
2. **What happens in a candle, a kerosene lamp, and a gasoline lamp when they produce light?**
3. **How is gas used for producing light?**
4. **How is an electric-light bulb constructed?**
5. **How is electricity used for lighting?**

SUGGESTIONS AND HELPS FOR STUDY

1. Problem 1 is a historical question which will require considerable reading from special references.

2. You can find some material for problems 2, 3, 4, and 5 by examining and experimenting with various lighting devices in your own home.

3. In connection with problem 4, secure an electric light bulb at home or from your teacher and see how the electricity enters and passes through the bulb.

4. You may find the following new words in this study:

capillarity—the cause of the rising of liquids in small tubes.

luminous—giving light.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 66. What happens when a candle burns?

Light a large candle. When you look at the flame closely you will probably be able to see that it is made up of three zones. What is the color of each zone?

FIG. 140

Hold a wooden splint across the flame a short distance above the wick. Remove it as soon as it catches fire and extinguish the flame quickly. Is all of the wooden splint that was in the flame burned? Which zone of the flame is the hottest? Which is the coolest?

Hold a dry, cold, clean pint jar over the candle flame for one minute with the opening of the jar about two inches from the flame. Examine the jar. What has collected on it?

Repeat the experiment with the jar. Put a small amount of clear limewater into the jar. Cover it and shake well.

Does anything happen to the limewater? This is a test for carbon dioxide. What are the products of a burning candle?

Record the notes of this experiment in your notebook.[1]

Experiment 67. Does oil rise in a wick?

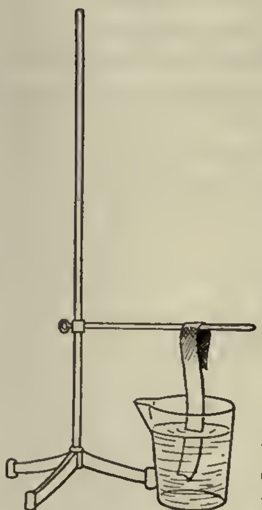


FIG. 141

Try to light a dry lamp wick. Does it burn? Suspend the wick over a glass. Pour kerosene into the glass so that about an inch of the free end of the wick is covered. Does the oil move up through the wick? What is the name of the force that causes the kerosene to rise through the wick? Light the wick and compare the flame with a candle flame.

Record the notes of this experiment in your notebook.[2]

Experiment 68. How does a kerosene lamp work?

Examine a common kerosene lamp (Fig. 146). Notice how the wick extends into the bowl of kerosene. How does the kerosene rise to the top of the wick? How does air get into the flame? What is the purpose of the lamp chimney? Cover the top of the lamp chimney with a piece of glass while the wick is lighted. What happens? Explain.

Record the notes of this experiment in your notebook.[3]

Experiment 69. What makes a gas flame give light?

Attach a Bunsen burner to a gas outlet. Close the air opening at the bottom and light the burner. Notice how luminous the flame is. Hold a white porcelain cup or crucible in the flame. The black deposit formed is unburned carbon which glows when heated.

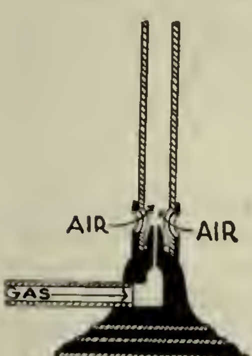


FIG. 142

Now open the hole at the bottom of the Bunsen burner and notice that the flame becomes pale blue in color and is almost non-luminous. Hold a white porcelain cup in this flame. Does a black deposit form?

Light a candle and hold a white object in the flame. What forms on it? What makes a flame give light?

Record the notes of this experiment in your notebook.[4]

Experiment 70. How is an electric-light bulb constructed?

Secure an electric-light bulb that has a tip on the end. One that is burned out will do for the experiment. Wrap your hand in a towel, hold the bulb under water, and break off the glass tip with a pair of pliers. What happened? Explain.

[1] See workbook, p. 36.
[2] See workbook, p. 36.
[3] See workbook, p. 36.
[4] See workbook, p. 37.

Examine the filament inside the bulb. Find out what it is made of.

Connect a very thin piece of iron wire between the two terminals of a good dry cell. Notice how hot the wire becomes. This is because the wire offers resistance to the electrical current. The filament in an electric-light bulb is so highly resistant to electricity that it becomes white hot without melting and gives off light.

Record the notes of this experiment in your notebook.[5]

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Make a study of the lives of Thomas Edison and Sir Humphry Davy.
2. Make a collection of candles, candlesticks, kerosene lamps, gas lights, and incandescent bulbs.
3. Make a study of the history of electric lighting.
4. Make a study of the history of gas lighting.
5. Make a miner's safety lamp.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How did the people of olden times light their homes? Primitive peoples probably had no other

FIG. 143. THE DEVELOPMENT OF LIGHTING

source of artificial light than the open fires they built in their cave homes. Some time later the smoky pine torch which could be carried from place to place was discovered. The next important development was the invention of the lamp filled with fat in which was embedded some form of wick. These lights were very crude and inefficient. They gave off much smoke and ofttimes disagreeable odors. The candle, which was more efficient than any of the preceding devices and was made by embedding a wick in solid fats and later

[5] See workbook, p. 37.

in paraffin, followed. It became the principal source of artificial illumination for several centuries until after 1850. With the discovery about 1860 of how to produce fuels from crude petroleum came the kerosene lamp.

The greatest developments in artificial illumination have taken place during the past hundred years. The invention of the incandescent bulb by Thomas Edison and the refinements made on it since by other workers are probably the outstanding contributions of this period and are greatly responsible for the brilliant illumination found today in our homes and communities.

FIG. 144. REPLICA OF EDISON'S FIRST ELECTRIC LIGHT

What happens in a candle, a kerosene lamp, and a gasoline lamp when they produce light? A candle flame is composed of three distinct regions. The central, cone-shaped region, which appears darker than the rest of the flame, is transparent and gives off very little light. The bright yellow section of the flame furnishes most of the light. Along the outer edge of the flame is a pale blue region which can be seen if the candle is brought close to the eye.

If you hold a wooden splint across the lower part of the flame until it just starts to burn, then withdraw the splint quickly and extinguish the flame, you will notice that the part of the splint that was in the central part of the flame is not charred. Since this region is transparent and not burning, of what does it consist? If you blow out the burning candle and bring a lighted match within a quarter of an inch of the wick it will burst into flame again. This shows that a combustible gas or vapor is near the wick. Where does this gas come from?

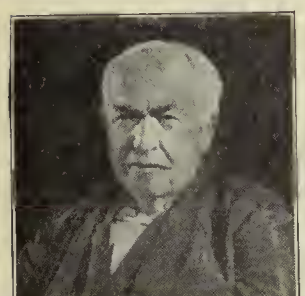


FIG. 145. THOMAS A. EDISON

The heat from the flame of the burning candle melts the solid paraffin (see Fig. 140). No doubt you have observed the melted wax in the cup formed at the base of the wick. The melted wax is absorbed by the wick and rises to the top of it by *capillary attraction*. Here it is changed by the intense heat to a gas and burns. It should be clear now that it is not the solid portion of the candle which is burning, but a gas produced from it.

Candle wax contains carbon and hydrogen. As it burns, oxygen in the air unites with the carbon to form carbon dioxide. In the pale blue region of the flame practically all of the carbon is burned. In the yellow region much of the carbon is unburned because of a lack of sufficient oxygen in that area. The unburned carbon goes off into the air as smoke. While the unburned particles are in the flame, the heat causes them to glow, and this is the source of the light. If sufficient air is mixed with a gas flame, the entire

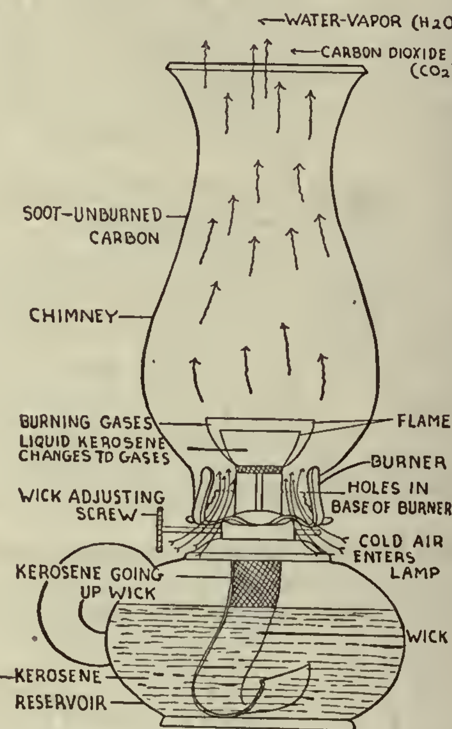


FIG. 146. KEROSENE LAMP

flame will be pale blue and will give off very little light. Have you ever noticed this in a gas stove where we are interested in obtaining heat and not light? The hydrogen combines with oxygen from the air also and forms water. The products of a burning candle then are water and carbon dioxide.

Much that we have learned about the candle also applies to a kerosene lamp. In the candle we started with a solid which was changed to a liquid and then to a gas, while with a kerosene lamp we begin with matter already in the liquid state. The common kerosene lamp has a wick that extends into a bowl of kerosene. The kerosene is absorbed by the wick and rises to the top of it by capillarity. When the wick of the lamp is lighted, the heat formed changes the liquid kerosene into a gas which burns when mixed with air. As the kerosene is vaporized by the heat, more of it rises from the bowl through the wick. As the wick is slowly used up, it is turned up by means of a screw that is a part of the burner.

Kerosene is another chemical compound containing the elements carbon and hydrogen. They unite with oxygen from the air to form carbon dioxide and water. As in the candle not all of the carbon is oxidized. The particles of unburned carbon are heated to glowing as they pass through the flame and give off light. If the wick is kept well trimmed and never turned too high, and the air holes of the burner are kept open and clean, nearly all of the carbon is burned before escaping from the flame. This makes the kerosene lamp much more efficient than a candle.

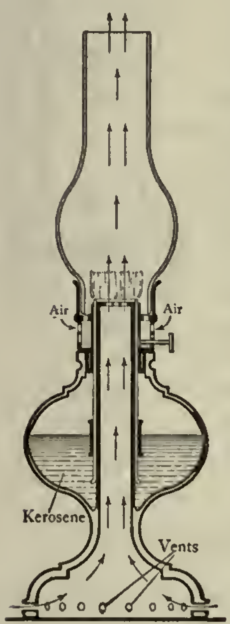


FIG. 147. CENTER DRAFT KEROSENE LAMP

A more modern type of kerosene lamp is shown in Figure 147. This lamp has a cylindrical wick instead of the flat one found in the common kerosene lamp. Another difference is that air is supplied through the base of the lamp and is carried up to the burner through a tube in the center. This lamp provides better light than the flat-wick type.

Exercise. *When a kerosene lamp is first lit, a thin film of vapor forms on the inside of the globe and then disappears. Knowing the composition of kerosene from your reading, establish a reasonable cause for this. Why does the film of vapor soon disappear? Would you expect this film to leave first from the base or the tip of the globe? Why?*

Gasoline is also used for home lighting. In many rural homes where gas and electricity are not available, gasoline has come into use to some extent. For the most part, gasoline does not give as much light as kerosene because the gas that is derived from gasoline contains very little solid carbon. Most of the gas from gasoline burns with a nearly colorless flame. To overcome this difficulty gasoline lamps are provided with a gauze mantle which is heated to incandescence by the intense heat of the flame and thus throws out a soft, white light. Gasoline lamps are commonly supplied with air pressure to force the liquid fuel to the burner. In the operation of this type of lamp it is necessary to pump air into the fuel tank with a pump.

How is gas used for producing light? As early as 1800 gas lighting systems that were designed by William Murdock, an Englishman, were used in a few English cotton and woolen mills. In this country at the present time both natural and artificial gas are used. In certain localities of the United States, a mixture of gases which is called *natural gas* comes from the ground. The chief constituent of this gas is methane, a compound of hydrogen and carbon, which burns with a luminous flame. Artificial gas is made from coal. It is sometimes made by passing steam over red-hot coal. This form of artificial gas is called *water gas.*

Two kinds of gas burners are employed for producing light. The *open flame* is the simpler type. It is simply a gas flame burning at the open end of a pipe,

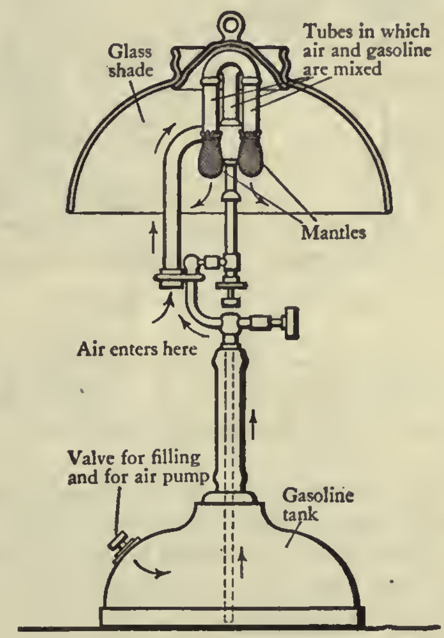


FIG. 148. GASOLINE PRESSURE LAMP

the supply of gas being regulated by a valve in the pipe. As in the candle and the kerosene lamp, some of the carbon in the gas is unburned. The particles become heated, glow, and produce a luminous flame. A fishtail flame spreader is frequently placed at the end of the gas pipe to spread the flame so that more light is produced. Gas lighting is greatly improved by use of the gas *mantle,* invented by Welsbach. The mantle is made of cotton treated with compounds of two rare metals, cerium and thorium. It is placed on the end of the gas pipe. When first lighted the cotton burns away, leaving an ash of cerium and thorium, which retains the appearance and form of the fabric. While this mantle is in the gas flame, it glows with great brilliancy, giving off an abundance of very bright white light.

How is electricity used for lighting? The first electric lamp was given to the world in 1879 by Thomas Edison after many years of persistent research. Edison searched diligently for a substance that could be heated to incandescence by electricity and yet not melt. His first lamp contained a carbon filament made

from thread, but this was soon replaced by a better filament made from bamboo. The bulb was exhausted of air to prevent the filament from burning.

All substances that conduct electricity offer resistance to the flow of electrical energy. There is no such thing as a perfect conductor. Some of the electrical energy is changed to heat energy, and when the re-

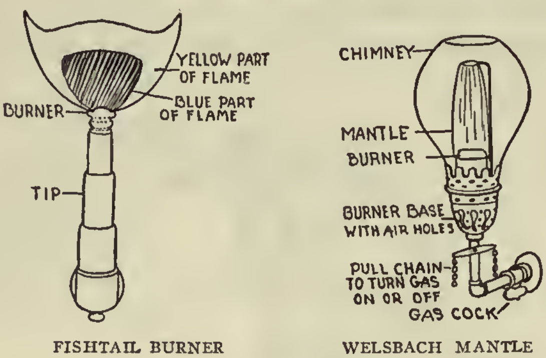


FIG. 149. TYPES OF GAS LIGHTS

sistance is very great, light may also be produced. Carbon was first used because it could be heated to 1850 degrees centigrade, give off white light, and still not melt.

The carbon filament lamp is fast being replaced by the tungsten light. Tungsten is a metal that can be heated to 2100 degrees centigrade without melting and in nitrogen-filled lamps to even higher temperatures. The higher the temperature, the more nearly the quality of light approaches sunlight and the greater is the amount of electrical energy changed to light.

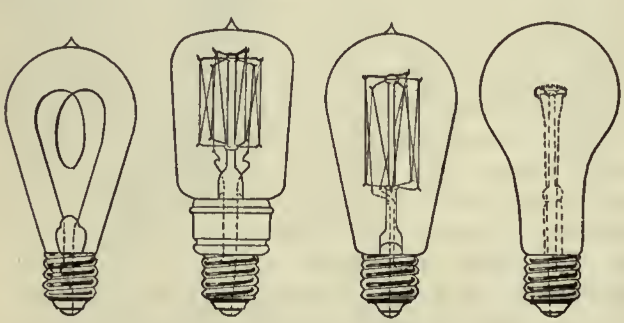


FIG. 150. DEVELOPMENT OF THE ELECTRIC LIGHT BULB

Until recent times all bulbs of incandescent lamps were exhausted to an almost perfect vacuum. The presence of air in the bulb would burn up the filament. However, in lamps of this kind the filament slowly evaporates and a dark coating of the metal forms on the inside of the bulb. Electric lamp manufacturers now make a bulb filled with some inactive gas, such as nitrogen or argon. These inactive gases slow down the evaporation of the filament, making it possible to heat the tungsten filament to higher temperatures than in the common vacuum bulb.

Gas-filled electric lamps are now being used for street lighting, and they are rapidly replacing the arc lamps used for this purpose.

Electric arc lamps, however, are still used for lighting. When two carbon rods are touched together and a current of electricity passes through them, the ends of the rods become very hot—hot enough, in fact, to turn some of the carbon into vapor. If the carbon rods are separated a quarter of an inch, the current continues to flow across the gap carried by the carbon vapor. A very brilliant light which formerly was used for street lighting and in stereopticon lanterns and in the early motion-picture machines is thus produced. Figure 151 shows a drawing of a carbon arc lamp. You can make a simple carbon arc lamp by using two lead pencils for carbons and a dry-cell battery as a source of electricity. See if you can plan and build such a lamp.

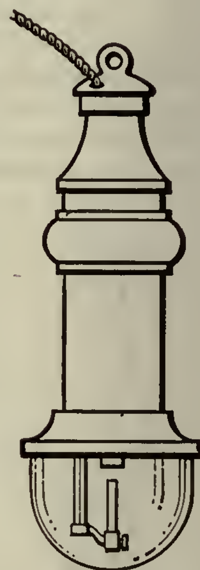


FIG. 151. ELECTRIC ARC LAMP

REFERENCES FOR FURTHER STUDY

Texts

Lake, Harley, and Welton, *Exploring the World of Science,* Unit 11

Pieper and Beauchamp, *Everyday Problems in Science,* Unit 15

Watkins and Bedell, *General Science for Today,* Chap. 22

Webb and Beauchamp, *Science by Observation and Experiment,* Unit 1 (part)

Special references

Faraday, *Chemical History of a Candle*

Bachman, *Great Inventors and Their Inventions*

General Electric Lecture Service, Schenectady, N.Y., *Inventor and Lamp* (Lecture 8)

Tappan, *Modern Triumphs*

Tappan, *Wonders of Science*

Luckiesh, *Lighting the Home*

Percival, *The Electric Lamp Industry*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. What the ancient methods of securing light were.
2. How new and better methods of lighting were developed as civilization advanced.
3. An understanding of the incandescent lamp and its advantages.

TEST OF MASTERY OF THE TOPIC

In your notebook comply with the instructions and complete the statements.

1. List four methods of artificial lighting in the order of their historical appearance.
2. Name all the sources of light that you can think of.
3. Write a paragraph on how a candle gives light.
4. Write a paragraph on how a kerosene lamp burns.
5. The incandescent lamp was invented by ____.
6. The filament of the first incandescent lamp was made of ____. The filaments of modern incandescent lamps are made of ____.
7. There are two types of gas lamps in common use today: those with ____ and those with ____.
8. In the carbon arc lamp ____ conducts the current across the gap between the two carbons.
9. Two common liquid fuels used as a source of light energy are ____.
10. Light is a form of energy. Can you suggest where kerosene and gasoline might have secured their energy?
11. Scientists have long been seeking a source of cold light. What do you think the greatest advantages of such a light source would be if it could be supplied generally for artificial illumination?

TOPIC 2. SOME IMPORTANT THINGS ABOUT LIGHT

SUGGESTED PROBLEMS AND QUESTIONS

1. **What do scientists think light is?**
2. **What is the speed of light?**
3. **What causes shadows?**
4. **What happens when light strikes an object?**
5. **What is the law of reflection?**
6. **Under what conditions are rays of light refracted?**
7. **What is the composition of sunlight? Under what conditions will an object appear black? White? Red?**
8. **What are some other ether waves?**

SUGGESTIONS AND HELPS FOR STUDY

1. Read the problems carefully and be certain that you understand them before you begin your reading.
2. Do as many experiments as you can as you work out each problem.
3. Devise an experiment to answer problem 6. Consult other general science textbooks for suggestions.
4. In connection with problem 7 obtain from your teacher a glass prism with which to experiment.
5. In the study of this topic the following new words may be met for the first time. Study them carefully and use them as frequently as possible.

opaque substance—substance which does not permit light to pass through it.
transmit—permit to pass through.
reflect—turn back.
refract—bend.
translucent substance—substance which will transmit light but which cannot be seen through.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 71. How does light travel?

FIG. 152

Set up apparatus as shown in Figure 152.

When the holes in the cardboard are not in a straight line, can you see the light?

From these data what inference can you draw as to how light travels?[1]

Experiment 72. What does a pinhole camera show about how light travels?

Obtain a small cardboard carton. An empty cereal box will do. Construct a pinhole camera by punching a tiny hole in the center of the bottom of the box. Cover the other end of the box with a piece of translucent paper. Wax paper may be used. Arrange the materials as shown in Figure 153.

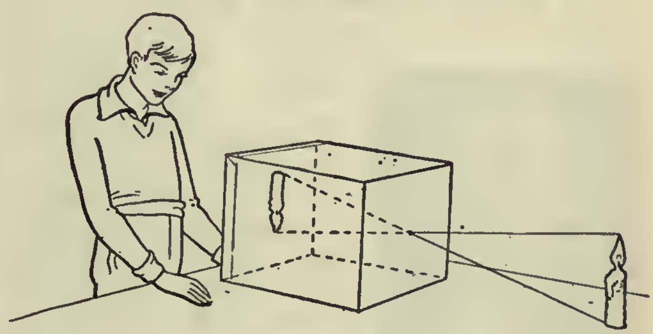


FIG. 153

Look at the image of the candle on the translucent paper. In what position is the image? Do these data support the data of Experiment 71? What conclusions are you now ready to draw as to how light travels?

Experiment 73. Will light rays bend?

a. Place a coin on the bottom of a fairly deep empty pan. Place yourself so that you can just see the edge of the coin. Have someone pour water into the pan. Does the coin seem to change position? How do you account for this?

FIG. 154

b. Hold a stick or pencil at an angle in a glass of water. Does it appear to be broken at the surface of the water? Does the part of the stick under the water appear to be bent upward? Explain.

Experiment 74. What causes color?

Hold a glass prism to your eyes and look at some object through it. Notice the colors which resemble a rainbow. These are called spectrum colors.

[1] See workbook, p. 38.

Darken a room and allow a little sunlight to enter through a small opening. Hold a prism in the sunlight so that the colors produced are thrown on one of the walls of the room. Hold a piece of white paper in each color on the wall. Hold a piece of red paper in each color. Hold a blue substance in each color. Hold a black substance in each color. Hold a lens in the color beam.

Record your results and complete the following statements.

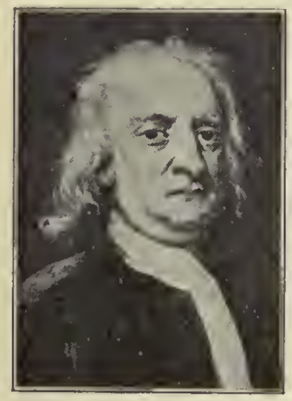
There are ____ spectrum colors. The colors of the spectrum in the order of their appearance on the wall are ____. An object is white if it (reflects, absorbs) ____ all the colors of the spectrum. An object is red if it reflects only the ____ part of the spectrum. An object is black if it ____ the colors of the spectrum. Placing the lens in the color beam proves ____.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

Examine various kinds of fabrics by means of sunlight. Repeat the examination by light from an ordinary incandescent bulb; by any other sources of light.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What do scientists think light is? Scientists at the present time are not certain that they know the exact nature of light. Sir Isaac Newton, a great scientist of the 17th century, thought that light consisted of streams of very tiny particles or corpuscles, as he called them, projected with rapid speed from all luminous bodies. Because of Newton's great reputation in the field of science this theory practically dominated scientific thought for more than a century.



International News Photos

FIG. 155. SIR ISAAC NEWTON
His best known achievement is the formulation of the laws of gravitation.

Today light is considered to be a wave motion. The question that arises, however, is, "What does this wave motion travel in?" You learned in a previous unit that sound is a wave motion in such things as air, water and other substances and that sound waves will travel only in solids, liquids, and gases. Light, however, will travel across a vacuum. Light comes to us from the sun, a distance of about 93,000,000 miles, and most of the space which it traverses we believe to be a perfect vacuum. Since we cannot conceive of a wave motion without something to "wave," scientists have found it necessary to assume a wave-transmitting medium. This medium is called the *ether* and it is assumed that it penetrates all space, even between the molecules of matter. The best definition that we can make for light at the present time is that light is a *wave motion in ether*. Even though this idea is being questioned today by some scientists, the beginner in science will find it best to accept this as a working definition until the nature of light is better understood.

What is the speed of light? Light travels at the tremendous speed of 186,264 miles per second. This speed is so enormous that up to the year 1675 it was thought that light traveled instantaneously, that is, that no time was consumed when light passed from one point to another. The great scientist Galileo had tried to measure the speed of light as a beam of it passed from one hilltop to another, but was unsuccessful. Roemer, a young Danish astronomer, about 1675 was the first to discover the approximate speed of light, and recently Professor Michelson, who was professor of physics at the University of Chicago, spent nearly a whole life time making the most accurate determinations.

International News Photos

FIG. 156. A. A. MICHELSON

The speed of light varies with the density of the substance through which it is traveling. The denser the substance the lower the speed. The speed of light is greatest in a vacuum and it is greater in air than in water or glass.

Exercise. *What causes shadows? See how much information you can secure about shadows by experimenting.*

Suggestions: Use a darkened room, a bright source of light, and a light screen such as a white wall, a piece of white cardboard, or a white sheet. Place various objects in the path of the light beam. Can you find answers to these questions?

Which kinds of objects cast shadows and which do not?

Are shadows equally intense at all points? Hold a cardboard in the light beam first near the screen and then farther away from the screen to study this.

Do shadows have depth, or are they only in the plane of the screen? Record the results of this exercise in your notebook.

Light travels in straight lines. By common experiences we know that it is impossible for us to see a source of light when an object through which light cannot pass is placed between our eyes and the source. Also it is impossible to see around a corner. This is because, under ordinary conditions, light rays travel in straight lines through a given substance. This can be shown by the experiments suggested at the beginning of this topic. Have you tried them?

What happens when light strikes an object? Three things may happen to light rays when they strike an object. Some of the light may pass through the substance, some will be absorbed, and some will be reflected. Substances which allow enough light to pass through them so that objects can be readily seen are called *transparent* bodies. Glass, water, and air are good examples. Substances which transmit light, but not enough to distinguish objects through them, are *translucent* bodies such as ground glass, oiled paper, and cotton cloth. Substances which transmit no light are called *opaque* bodies. All substances reflect some of the light which strikes them and all absorb a part of it. A mirror is an object that reflects nearly all the light it receives.

Nearly every person has experienced that helpless feeling at night in a dark room when one is unable to see anything. We are able to see an object only when light is present and reflected by the object to our eyes. Most objects have rough surfaces so that the rays of light which strike them are reflected in an irregular manner, being thrown off in different directions as shown in Figure 157. This is called *diffuse reflection* and produces diffused light. When parallel rays of light strike a very smooth, flat surface, however, the light is reflected to our eyes as parallel rays as shown in the figure. This is called *regular reflection* and makes it appear as if the light were coming from a distant object rather than from a reflecting surface. In other words, we see the image of the source of light rather than the reflecting object. Any object so highly polished that it will produce an image of the source of light is called a mirror.

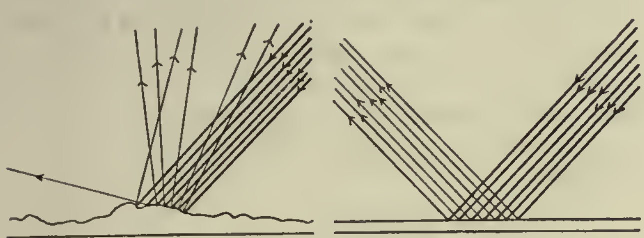


FIG. 157. DIFFUSE AND REGULAR REFLECTION

Diffuse reflection plays an important part in our everyday life. Sunlight is reflected in all directions by smoke and dust particles in the atmosphere. If this condition did not exist we should see only the brilliance of the sun and darkness everywhere else. Thus we see that light is reflected several times. It is reflected first by the "sky," then by objects on the earth, and indoors by the walls of the rooms of our houses. In this way a soft, diffused light is produced which is more pleasing to the eye than the glaring light direct from the sun.

What is the law of reflection? Mirrors are sometimes placed at dangerous road turns to enable cars coming from the other direction to be seen. Have you ever observed that rear-view mirrors used in automobiles are set at an angle so that light coming through the back window may be reflected to the eye of the driver. A ray of light which strikes a mirror is sometimes called an *incident ray* and the ray which leaves the mirror, the *reflected ray.* If a line is drawn at right angles to a mirror where the incident ray strikes, as shown in Figure 158, the angle between the perpendicular line and the incident ray will be found exactly equal to the angle between the reflected ray and the perpendicular line. This is known as the law of reflection.

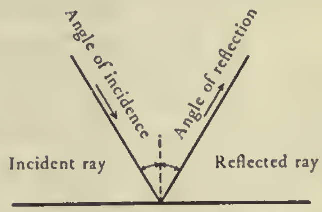


FIG. 158. ANGLES OF INCIDENCE AND REFLECTION

Under what conditions are rays of light refracted? Have you ever noticed that the bottom of a dish of water or the bottom of a stream appears to be nearer the surface than it really is? A straight stick held slantingly in the water and looked at from the side seems to be bent upwards at the point where it enters the water. It was stated previously that light travels in straight lines, but this is true only when light is passing through a medium of a fixed density. When light passes at an angle from a medium of one density to a medium of a greater or lesser density, the light rays bend. This accounts for the apparent shifts of the positions of objects when seen under water. This bending of light rays is called *refraction.* The general rule is that light passing at an angle from a dense to a less dense medium, as from water to air, is bent away from the perpendicular, while light passing at an angle from a medium of lesser density to one of greater density is bent toward the perpendicular. See Figure 160.

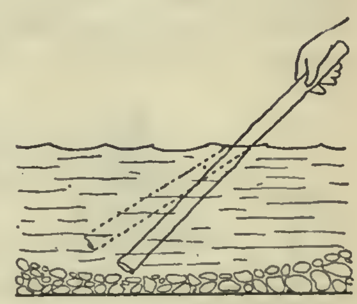


FIG. 159. REFRACTION OF LIGHT BY WATER

Exercise. *If you wished to shoot fish in a clear stream, would you aim a gun above or below it to make certain of hitting it? Why?*

What is the composition of sunlight? We have

learned that light is a wave motion in the ether. However, sunlight does not consist of waves of just one wave length but a mixture of waves of different wave lengths. Each wave length produces its own characteristic color while all of them together produce white light. This can be shown to be true by passing a ray of sunlight through a glass prism (see Fig. 161) which spreads the light so that all the colors show. The set of color bands produced by the prism is called a *spectrum*. There are seven spectrum colors and they always appear in the following order: red, orange, yellow, green, blue, indigo, and violet.

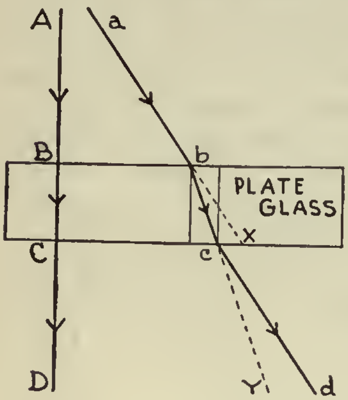


FIG. 160. LIGHT THROUGH PLATE GLASS
ABCD—PERPENDICULAR RAY
abcd—SLANTING RAY

Light waves are extremely short waves, especially in comparison with the length of sound waves. The following table gives the approximate wave lengths in centimeters for six colors.

WAVE LENGTHS OF LIGHT

Red	0.000068 cm.	Green	0.000052 cm.
Orange	0.000063 cm.	Blue	0.000046 cm.
Yellow	0.000059 cm.	Violet	0.000040 cm.

The color of an object, when sunlight illuminates it, depends upon the wave lengths which the object reflects or transmits. A piece of white paper is white because it reflects all wave lengths of the spectrum equally. An object is red if it reflects only the wave length that produces red while the other waves of the spectrum are absorbed. An object that absorbs all the light waves of the spectrum appears black; blackness really means a total absence of color.

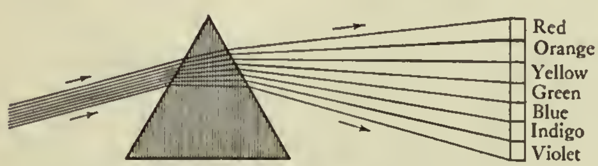


FIG. 161. BREAKING UP OF SUNLIGHT BY A PRISM

Objects looked at under artificial light do not show their true colors because artificial light is generally deficient in some of the spectrum colors. It is always safer to select goods and clothing under natural light.

The rainbow is one of our most common displays of the spectrum. It is usually seen early in the morning or late in the afternoon when the sun's rays come through the clouds while rain is still falling. If a rainbow occurs in the morning it is usually seen in the west while an afternoon rainbow shines forth in the east. One must have his back to the sun to see a rainbow.

As the rays of sunlight enter raindrops, the light is bent and reflected. Thus the white light is broken up into its various wave lengths as it was by the prism. Each raindrop sends out the whole range of spectrum colors from red to violet, but at different angles. Therefore, a drop high up above the earth may send only red rays direct to the eye while the others at different angles pass by. In the same manner a drop of water at a lower altitude may be at the correct angle to send only the violet waves directly to the eye, all other waves passing by. Between these drops others furnish the orange, green, and blue waves so that the eye sees a continuous color band or spectrum across the sky. Figure 162 shows how a raindrop breaks the light ray into its wave lengths.

If sunlight strikes raindrops at still higher altitudes, the light may be twice reflected and refracted inside the drop and thus cause a second rainbow above the other one. Figure 163 shows how this happens and why the spectrum colors are reversed in order in this second bow.

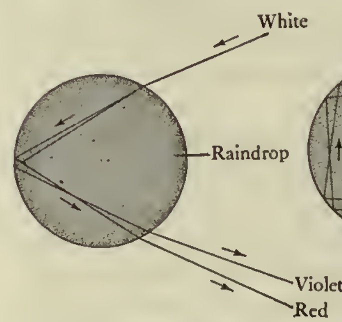


FIG. 162. DROP OF WATER WITH SINGLE REFLECTION

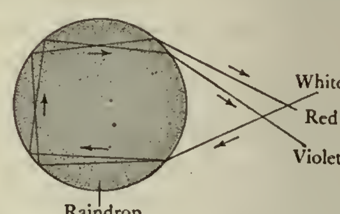


FIG. 163. DOUBLE REFLECTION INSIDE A RAINDROP

What are some other ether waves? The human eye is able to see only a comparatively short range of wave lengths, but beyond each end of the spectrum there are longer and shorter ether waves that do not affect the optic nerve of the human eye. Beyond violet, the shortest wave of the spectrum, are the invisible ultra-violet rays that are given off in great quantity by the sun. We mentioned in the study of foods that these rays exert a beneficial influence upon living things and produce the same effect in the human body as vitamin D.

They are also responsible to a large extent for the chemical action that takes place on a photographic film; this is the reason we get our best snapshots between about nine in the morning and four in the afternoon. Ultra-violet rays also produce sunburn,

with which we are not bothered indoors because the rays are easily absorbed by matter such as ordinary window glass. A glass has recently been made which does allow ultra-violet rays to pass through it, but it is more expensive than common glass.

At the other end of the spectrum, beyond the red waves, exist the longer, invisible infra-red rays. We cannot conceive of their color because we cannot see them. We are familiar with the infra-red rays as heat rays from a fireplace or hot stove.

Radio and wireless waves are still longer ether waves. As you probably know, many of our broadcasting stations broadcast on ether waves from about 200 to 500 meters in length.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 26
Clement, Collister and Thurston, *Our Surroundings,* Chap. 13
Hunter and Whitman, *My Own Science Problems,* Unit 6; *Science in Our World of Progress,* Unit 6; *Science in Our Social Life,* Unit 6
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 21
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 15
Powers, Neuner, and Bruner, *This Changing World,* Chap. 20 (part)
Skilling, *Tours through the World of Science,* Tour 13
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 8
Watkins and Bedell, *General Science for Today,* Chap. 22
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 1 (part)
Wood and Carpenter, *Our Environment: How We Use and Control It,* Unit 2, Topic 8

Special references

Black and Davis, *Practical Physics*
Godinez, *The Lighting Book*
Lynde, *Physics of the Household*
Luckiesh, *Artificial Light*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of the laws of reflection.
2. An understanding of the principles of refraction.
3. How light from the sun is used for illumination.
4. A knowledge of the composition of natural light.
5. A concept of light as a form of energy.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. When light strikes an opaque object it is ____ and ____.
2. The angle of incidence is ____ to the angle of ____.
3. Black surfaces are black because they ____ all the colors.
4. White surfaces are white because they ____ all the colors.
5. When a white light falls on a red surface it reflects only the ____ portion of the light and ____ the other colors.
6. ____ is the most dependable light for judging colors.
7. Materials that allow no light to pass through them are called ____ bodies.
8. When light passes from a medium to one of greater or lesser density the light rays are ____.
9. When a ray of sunlight passes through a prism, the ray is ____ so as to give ____.
10. Make a definition for light.
11. By a drawing show an arrangement of plane mirrors by means of which a soldier in a trench could see over the top of the trench without exposing himself. Trace the light rays from an object through the instrument to the eye of an observer. Can you make such a device that will work?
12. The longest waves of the visible spectrum are ____ while the shortest ones are ____.
13. Infer a reason for lampshades' being made of translucent glass and electric light bulbs' being frosted.
14. The rainbow is caused by slanting rays from the sun shining through ____.
15. Ether waves that are longer than the red of the visible spectrum are called ____ rays or ____ rays. Those ether waves that are shorter than the violet waves of the visible spectrum are called ____ waves.

TOPIC 3. PROPER LIGHTING IN THE HOME

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is the relation of distance to the intensity of light?**
2. **How do the walls and the ceiling of a room affect light?**
3. **What are the different methods of lighting?**

SUGGESTIONS AND HELPS FOR STUDY

1. Problem 1 can be answered very readily by doing Experiment 75.

2. In connection with problem 2, investigate in your home and some public building the conditions mentioned.

3. The methods of lighting mentioned in problem 3 are described in the readings below and the texts listed for reference. Try to find buildings in which each method of lighting is used, however, in order to get some first-hand information.

4. Try to determine which form of lighting would be the most economical and hygienic to use in your surroundings.

EXPERIMENTS OR DEMONSTRATIONS THAT WILL HELP ANSWER THE PROBLEM QUESTIONS

Experiment 75. What is the relation of the intensity of illumination to distance from the light source?

Cut a hole one inch square in the center of a piece of cardboard about six inches square. Darken the room. Hold a flashlight one foot in front of the cardboard. Mark off in

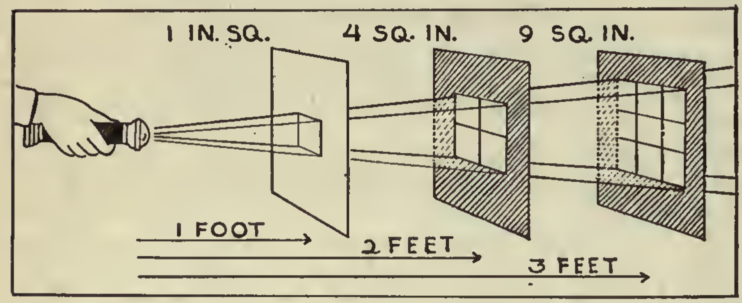


FIG. 164

square inches another piece of cardboard about sixteen inches square and hold it one foot back of the first cardboard.

a. How many square inches of the second cardboard are illuminated?

b. Move the cardboard marked in square inches two feet from the first cardboard. Now how many square inches of the cardboard are illuminated?

As in all other experiments, record notes and complete the incomplete statements in your notebook.[1]

As the distance from the light source increases, the same amount of light is spread over ____ areas. This means that each ____ receives ____ light.

Experiment 76. How is your home lighted?

Make a survey of lighting in your home. What methods of artificial illumination are used at night? What is the source of light during the day? Do you have indirect, direct, or semi-direct lighting? What kinds of walls and ceiling are in your home? If electricity is used to produce light, what types of incandescent bulbs are in use? What is the watt rating of the bulbs used in the living room? How many bulbs are in use in the living room? What suggestions can you make for the improvement of the lighting in your home?

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Investigate the lighting system used in your schoolhouse; your church; an auditorium.
2. Learn to read a gas meter.
3. Learn to read an electric meter.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is the relation of distance to the intensity of light? The amount of light we receive from any source depends upon the intensity (brightness) of the source and the distance we are from it. From our everyday experience we observe that the nearer an object is to a source of light, the more brightly it is illuminated. If you have performed the first experiment described in this topic, you will have learned that when an object is moved twice as far from the source it receives only one fourth as much light. If the object were moved four times as far from the source of light it would receive only one sixteenth as much light. We see from this that the intensity of light decreases rapidly with increase in distance from the source.

How do the walls and the ceiling of a room affect light? The amount of light reflected from the walls and ceilings of a room depends upon the color and the nature of the surface of the decorations. The following table shows the percentage of diffused light which differently colored walls and ceilings will reflect.

Color	*Per Cent*	*Color*	*Per Cent*
Ivory white	76	Pink	51
Ivory	72	Light orange	50
Lichen gray	70	Silver gray	50
Pearl gray	70	Bright sage green	43
Primrose	67	Tan	37
Satin green	67	Sky blue	31
Chrome yellow	62	Cardinal red	27
Buff	59	Brown	18
Shell pink	58	Dark green	05
Cream	56	Maroon	05

A study of the table of colors shows that room decorations vary greatly in their capacity to reflect light. By selecting materials that reflect well we increase the efficiency of our lighting system and reduce the cost.

The nature of the reflected light must be considered, however, as well as the amount. Sufficient light without glare is desired. Strong, glaring light puts a strain on the eyes which may be prevented by the use of soft, diffused light. To produce good indoor illumination, decorations that will both reflect and diffuse light well should be selected.

Illuminating engineers have estimated that for proper daytime illumination in any room the window area should be about one-fourth the floor space of the room. This is an important factor in proper lighting of both the home and the school.

When new light sources began to replace the candle, the light-giving power of these lighting devices was compared to the intensity of light from a *standard candle*. This candle is made from a solid wax obtained from sperm whale oil and burns at the rate of 120 grains an hour. The illuminating power of this candle is called *candle power*. In recent years the candle power used in this and several other countries has been established by the use of standard electric-light bulbs maintained at the Bureau of Standards in Wash-

[1] See workbook, p. 39.

ington, D.C. This unit of the intensity of light is known as the *international candle.*

We have learned, however, that the illumination of an object depends not only upon the intensity of the light source but also upon the distance the object is from the light. A body five feet away from a 100-candle power bulb will receive only one-twenty-fifth as much light as the same body placed one foot from the bulb. To take into consideration these two factors, the unit in which illumination is measured must have both intensity and distance. This unit is called the *foot candle.* An object one foot away from a one-candle power light source is illuminated with an intensity of one foot candle. A tennis court on a bright sunny day has an illumination of about 10,000 foot candles while some factories working by artificial light have less than one foot candle.

The amount of illumination needed in our homes, schools, and factories varies. The following table gives the proper illumination for various conditions.

Illumination Required for Schools[1]

Assembly rooms	5 foot candles
Classrooms and studies	10 foot candles
Cloakrooms and corridors	2 foot candles
Drawing and sewing rooms	20 foot candles
Laboratories and manual training rooms	10 foot candles

Illumination Required for Homes

Halls and corridors	2 foot candles
Kitchen	10 foot candles
Bedrooms	5 foot candles
Sewing room	10 foot candles
Porch and basement	2 foot candles
Bathroom	5 foot candles
Dining room	2 foot candles
Living room and library	2 foot candles but with 10 foot candles under reading lights

The illuminating power of electric-light bulbs is more commonly expressed in watts than in candle power. The watt is the unit of measurement of the power of electricity. The relation between watts and candle power for different electric-light bulbs is known. An ordinary tungsten lamp requires about 1.25 watts per candle power. Thus a 60-watt tungsten lamp gives 60 watts $\div$ 1.25 or 48 candle power of light. How many candle power would a 100-watt tungsten lamp give? Figure 166 shows a device known as a foot-candle meter which has recently been developed for home use. From this instrument the illumination of any room may be read directly in foot candles.

What are the different methods of lighting? Electric

[1] From Lynde, *Everyday Physics,* by permission of the Macmillan Company, publishers.

Courtesy General Electric Company

FIG. 165. TYPES OF HOME ILLUMINATION

Upper—DIRECT LIGHTING

Middle—INDIRECT LIGHTING

Lower—SEMI-DIRECT LIGHTING

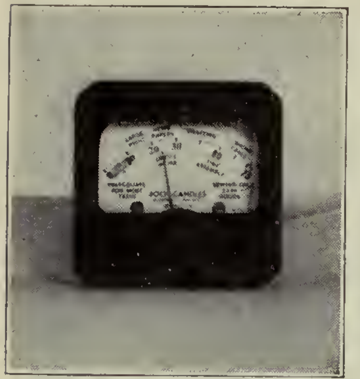


FIG. 166. FOOT-CANDLE METER

lighting units are now classed as direct, indirect, or semi-direct. See Figure 165. In choosing one of these types we should keep two important factors in mind: their efficiency and the nature of the light given off. In *direct lighting* at least one half of the light is thrown directly downward to the place where it is used. This is the most efficient lighting system because not so much of the light is lost by absorption or diffusion, but it is also the most likely to cause glare which is not good for the eyes.

In *indirect lighting* all of the light is reflected upward to a light-colored ceiling which gives off a soft diffused light to the room. This is the least economical lighting system, but it produces the most restful light for the eyes. It is commonly used in hospitals.

In *semi-direct lighting* the light passes through a translucent substance which eliminates glare. This method of lighting stands between the other two as to cost and softness of the light produced.

Illumination experts have recently designed new types of lamps for the home which are said to improve the illumination. In these lamps a reflector made of translucent glass provides a semi-direct light which is soft and restful to the eyes.

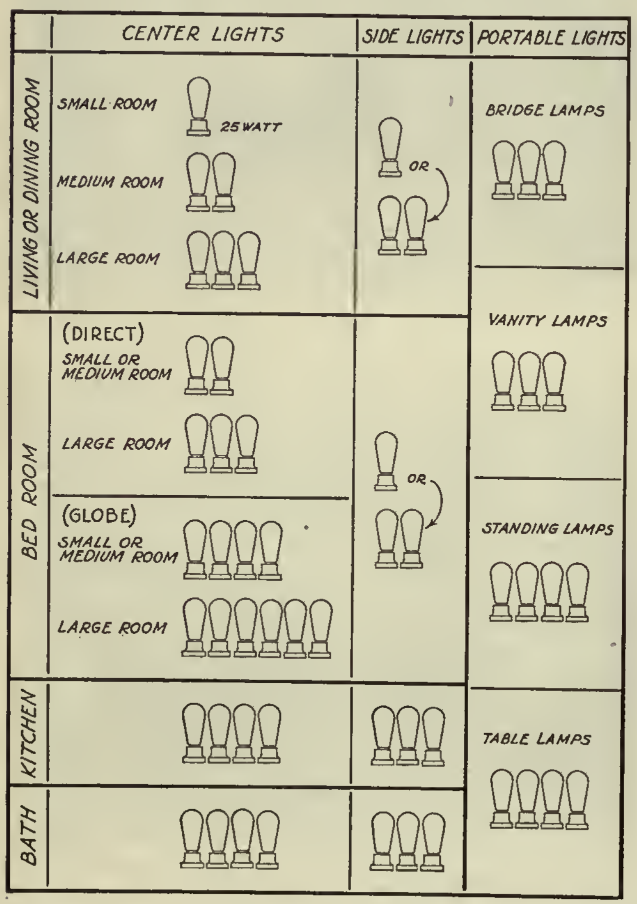


FIG. 167. DO YOU USE THE PROPER SIZE OF ELECTRIC BULBS IN YOUR HOME?

This illustration shows the proper number of watts to use for different types of fixtures. Each lamp represents 25 watts.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 26
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 13
Hunter and Whitman, *My Own Science Problems*, Unit 6; *Science in Our World of Progress*, Unit 6; *Science in Our Social Life*, Unit 6
Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 21
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 15
Skilling, *Tours through the World of Science*, Tour 13
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 8
Watkins and Bedell, *General Science for Today*, Chap. 22
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 1 (part)
Wood and Carpenter, *Our Environment: How We Use and Control It*, Unit 2, Topic 8

Special references

Lynde, *Physics of the Household*
Godinez, *The Lighting Book*
Luckiesh, *Lighting the Home*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the factors which determine the intensity of illumination in a room.
2. A knowledge of the advantages and disadvantages of direct lighting, semi-direct lighting, and indirect lighting.
3. An understanding of how artificial light is regulated in our buildings.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Illumination on any area ____ as the distance from the light source ____.
2. Rough surfaces ____ reflected light.
3. Three general systems of illumination in use at present are ____.
4. Light colored wall paper reflects light ____ than dark colored paper.
5. Describe a direct method of lighting.
6. Describe an indirect lighting system.
7. Describe a semi-direct lighting system.

8. A device for measuring the intensity of illumination of buildings is called a ____.

9. For proper illumination a schoolroom should have at least ____ foot candles.

10. For proper daytime illumination the window area of any room should be at least ____ of the floor space.

11. The unit of measurement of the power of an electric current is the ____.

12. An ordinary electric lamp of the tungsten type requires about ____ watts per candle power.

13. What are the most important factors to consider in judging the illumination of any room?

TOPIC 4. DEVICES WHICH USE LIGHT

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is a lens?**
2. **What are the parts of the human eye and how does the eye work?**
3. **Of what importance is the proper care of the eyes?**
4. **How are the eye defects, nearsightedness, farsightedness, and astigmatism, corrected?**
5. **What are the parts of a camera and how does a camera "take" pictures?**
6. **Do moving pictures really move?**
7. **What are some of the other optical instruments important to man?**

SUGGESTIONS AND HELPS FOR STUDY

1. Secure different types of lenses from your teacher and experiment with them. See Experiments 77 and 78.

2. In connection with problem 5, if you have a camera available, take it apart and examine the various parts. Make a diagram showing how an image is formed on the plate or film. See Experiment 79.

3. Make a diagram of the human eye and compare it with your diagram of a camera.

4. Illustrate problem 4 with diagrams.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANWER THE PROBLEM QUESTIONS

Experiment 77. What kind of image is formed by a convex lens?

Hold a convex lens at a window. Move a piece of white paper back and forth, back of the lens, until you find a place where an image of something out of doors is formed on the paper. The distance from the lens to the paper is the focal length of the lens. Measure this.

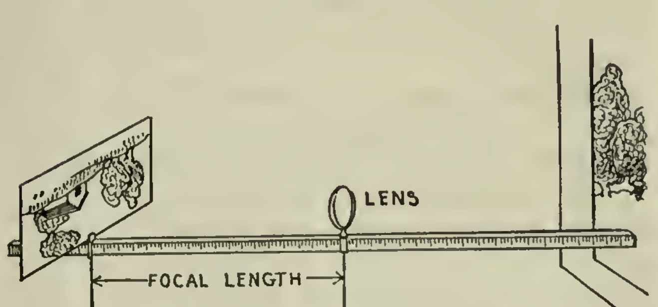


FIG. 168

Record the notes of this and other experiments in your notebook.[1]

Experiment 78. How does a reading glass enlarge print?

Examine an ordinary reading glass. What kind of lens does it contain?

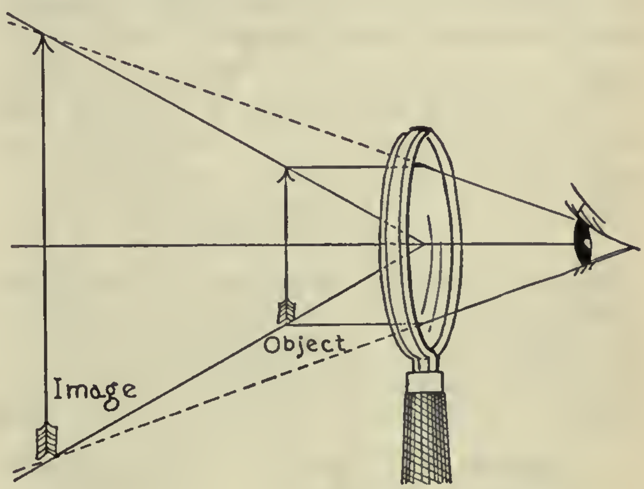


FIG. 169

Examine the diagram in Figure 169. Explain how a reading glass enlarges an object seen through it.

Experiment 79. How is a camera constructed and operated?

Examine carefully a focusing camera. Examine the diagram (Fig. 170) and note its essential parts. Explain how the image is formed. Explain briefly the functions of each of the following parts of the camera: shutter, diaphragm, lens, film or plate.

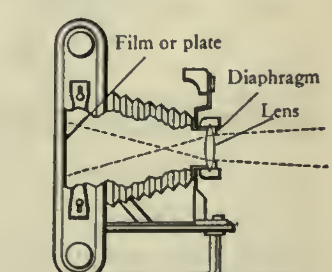


FIG. 170

Experiment 80. How can you make a simple telescope?

A simple telescope is easy to make if you have the following materials: two lens holders, a meter stick, a thin convex

[1] See workbook, p. 40.

lens, and a thick convex lens. Measure the focal length of each lens as instructed in Experiment 77.

Place a lens holder at each end of the meter stick. Put the thin convex lens in one lens holder and the thick lens

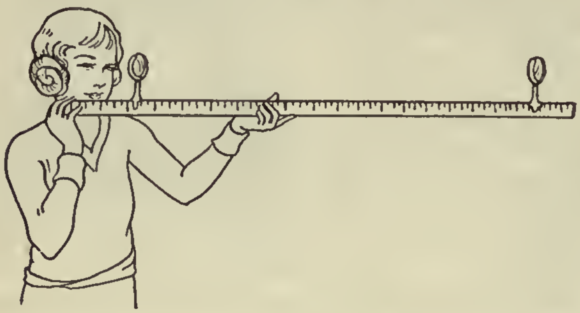


FIG. 171

in the other. Point the end of the meter stick with the thin lens toward some object. Keep your eye close to the thicker lens and move it toward the other lens until you can clearly see the object toward which it is pointed. Record your results.

The objective lens (the one nearer the object) had a ____ focal length than the eyepiece lens. The image of the object was (upright, inverted) ____. The image formed by the objective lens was ____ by the eyepiece lens.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is a lens? We learned in a previous lesson that light rays are bent in passing from a medium of one density through a medium of different density, as from water to air. This phenomenon we called refraction. Primitive man took this into account when

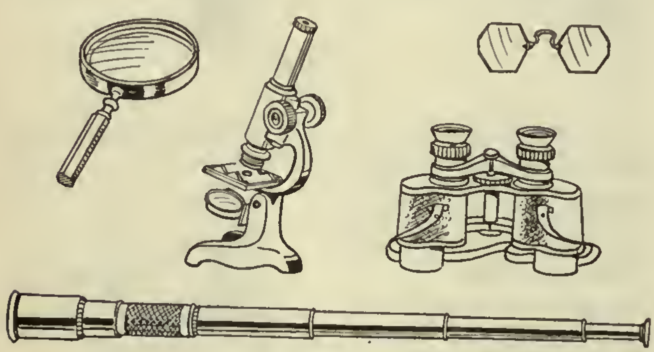


FIG. 172. INVENTIONS THAT EMPLOY LENSES

he speared a fish by aiming below the spot where the fish seemed to be in the water, even though he did not know anything about the science of refraction. It is only in more recent times, however, that man has learned how to make instruments that enable him to employ refraction in useful ways. Cameras, telescopes, microscopes, motion picture machines, and projection lanterns are a few of the inventions of this type which enable us to see more and better than we can with ordinary vision. All of these devices are called *optical instruments.*

In all optical instruments we find lenses; hence, in order to know how optical instruments work we must know about lenses and how they affect light passing through them. A lens in an optical instrument is a piece of glass with smooth spherical surfaces. Any other transparent substance with polished spherical surfaces is a lens also.

Lenses may be divided into two general classes. (Examine Fig. 174 carefully as you read this paragraph.) *Convex* lenses are thicker at the center than at the edges while *concave* lenses are thinner at the center than at the edges. Convex lenses are also called *converging* lenses because they bend to a point the light rays that pass through them. Concave lenses are known as *diverging* lenses because they spread the light rays coming to them farther apart.

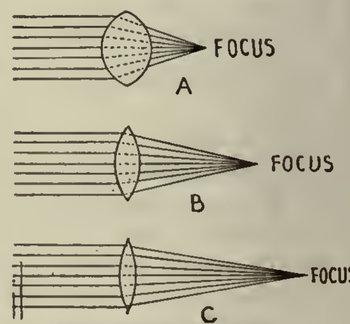


FIG. 173. FOCAL LENGTH OF CONVEX LENSES

If you hold a convex lens in direct sunlight and move a piece of paper back and forth behind the lens, you will find a point where the rays of sunlight passing through the lens are brightest. In a short while the paper may catch fire. This point at which the rays of light are brought together is called the *focus.* If the convex lens is replaced by a concave lens, the light rays passing

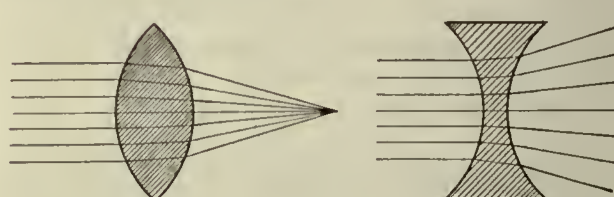


FIG. 174. THE EFFECT OF CONVEX AND CONCAVE LENSES ON PARALLEL LIGHT RAYS

through the lens will be spread farther apart instead of being brought to a point. The rule of lenses is that *light rays passing through a lens are always bent toward the thickest part.*

What are the parts of the human eye and how does the eye work? It contains a lens which forms images of objects that we look at. But in order to know how the eye works, we must first of all study its main parts and see how they work together. Study Figure 175 as you read the following. At the front of the eye is the covering of the eyeball called the *cornea* (kor′-nē-a). Back of the cornea is the colored part of the eye called the *iris* (ī′ris). In man this is normally some

shade of blue or brown. The opening in the iris is called the *pupil*, the size of which changes according to the intensity of light. The iris has in it two sets of muscles that regulate the size of the pupil. If you stand in front of a mirror in a dark room for several minutes and then turn on the lights you can see the pupils of your eyes change in size. Directly back of the iris is a convex lens. It is made of a soft, transparent substance, and its shape is changed by muscles

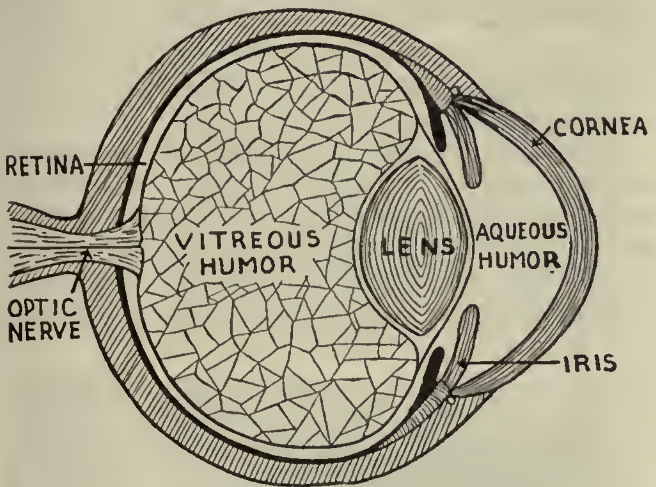


FIG. 175. CROSS SECTION OF THE EYE

attached to it. These accommodate the eye to changes in distance from the objects we look at. The large space between the lens and the *retina* is filled with a jelly-like, transparent substance called *vitreous humor.* This substance gives the eye its shape. The *retina* is connected to the *optic nerve* which leads to the brain.

With the exception of bodies such as the sun, the stars, a candle, or an electric light, which shine by their own light, we see all objects by reflected light. The reflected light rays from an object enter the pupil of the eye and pass through the double convex lens, which bends them so that an image is formed on the retina. This affects the optic nerve, which carries the sensation to the brain, and the brain cells interpret the message that it receives.

The statement was made in the preceding paragraph that the eye is built to accommodate for differences in distance from objects which we look at. That is, we can see near or distant objects. Do you know how it is done? Look at Figure 173. It shows that the distance of the image from the lens varies with the thickness of the lens. The thicker the lens, the nearer the image is to it. The distance of the image from the lens also changes as the distance of the object from the lens changes. The farther the object is from the lens, the nearer the image is to it. Since the retina, which receives the images in the eye, cannot move, it is always the same distance from the lens. The eye is so constructed, however, that it can change the shape of the lens. When objects are near, the lens becomes more rounded and bends the light rays at a greater angle, focusing them on the retina. When we are looking at objects far away the lens becomes thinner so that the rays of light can be focused on the retina without being bent so much.

Of what importance is the proper care of the eyes? The eyes are delicate organs and should be cared for as such. The loss of sight is one of the greatest tragedies of life.

The eye is naturally an organ of long-range vision, but many people, especially students, must do much close work. When we look at near objects, such as a book, muscles of the eye contract in order to make the lens thicker. This keeps the muscles of the eyeball under strain and they become tired just as other muscles of the body become tired. When one has to do a great deal of reading, it is a good thing to relax the eye muscles occasionally by looking at some distant object or by closing the eyes for a short time.

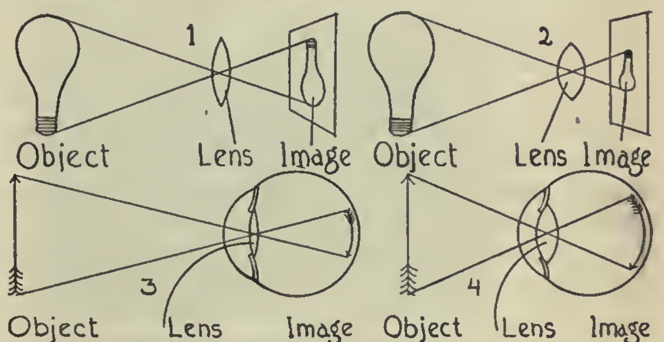


FIG. 176. HOW THE EYE ADJUSTS FOCUS

Never read or study while facing a well lighted window or lamp. It is best to have the light for reading and writing always coming from behind you over your shoulders. The page that one is reading should always be well lighted without glare.

Infections of the eyeball and lids are common, especially with children. They are known by various names such as sore eyes, pink eye, a sty, etc. For mild infections a concentrated solution of boric acid usually proves effective. It is always best, however, to be examined by an eye specialist and have him prescribe a remedy. By all means do not purchase patent medicines for the eye. Avoid them and consult a reliable physician.

How are the eye defects, nearsightedness, farsightedness, and astigmatism, corrected? The normal eye accommodates itself for distance so that the images of objects always fall on the retina in such a manner as to produce clear vision. Unfortunately many persons have imperfect eyes so that eyeglasses must be worn to help the eyes do their work properly. The

three common eye defects are *nearsightedness, farsightedness*, and *astigmatism.*

Nearsightedness is caused by images of objects falling in front of the retina when the focusing

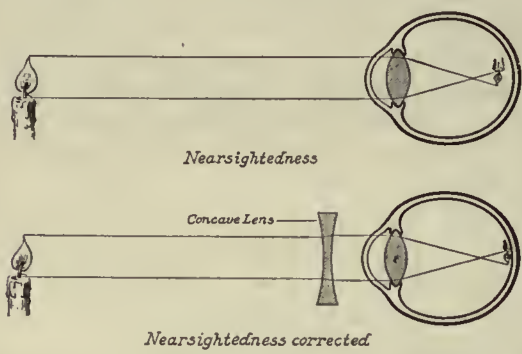


FIG. 177. NEARSIGHTEDNESS AND HOW IT IS CORRECTED

muscles are relaxed. Distant objects thus become indistinct. This defect is corrected by wearing eyeglasses made of concave lenses (Fig. 177). These tend to spread the light and thus throw the image back upon the retina.

Farsightedness is caused by the rays of light focusing beyond the retina. In other words, the rays of light strike the retina before an image has been formed. Farsightedness is not so easy to detect as nearsightedness because by muscular effort a farsighted person may be able to focus upon objects at almost any distance. It must be detected through indications of eye strain and fatigue rather than

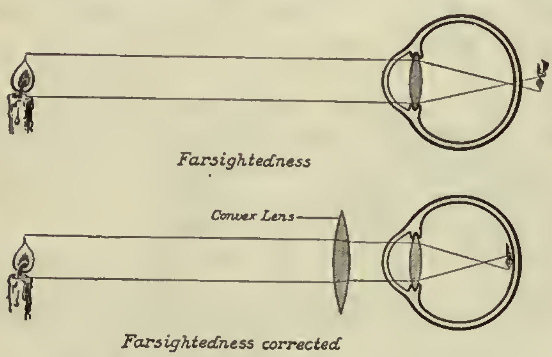


FIG. 178. FARSIGHTEDNESS AND HOW IT IS CORRECTED

through indistinctness. Strained facial expression and early fatigue are common symptoms of eyestrain, and the cause must be determined and corrected by an expert oculist. Farsightedness is corrected by convex lenses which tend to converge the light rays more and thus bring the image up to the retina (Fig. 178).

Astigmatism is caused by the lens or other parts of the eye being irregular in curvature so that different parts of the image are not in focus at the same time. This produces a distorted and blurred image on the retina. This defect is especially annoying to students and others who must do a great deal of reading or looking at lines. It is one of the causes of headaches and nervousness when not corrected. It can be remedied only by obtaining lenses ground to make up for the error in the eye.

If you find that you are unable to see clearly, or that you suffer from headaches, nervousness, or pain in the eyes, consult a reputable eye specialist at once. The early correction of minor eye defects may prevent serious trouble later. Always remember that seeing is the most precious sense we have and that the eyes, the organs of sight, are delicate, requiring great care to keep them healthy.

What are the parts of a camera and how does a camera "take" pictures? A simple camera is like the human eye in many respects. It is a light-tight box with a convex lens at one end and a place for a photographic film or plate at the opposite end. When a picture is taken, reflected light from the object is allowed

Courtesy Eastman Kodak Co.

FIG. 179. FIRST FOLDING KODAK

to pass through the lens for a short time, thus forming an inverted image of the object on the film or plate The surface of the film or plate usually contains a silver compound which is sensitive to light. Wherever the light rays strike the silver compound they cause a chemical action to take place. Where the light is strongest the compound is changed the most and where the light is weakest the compound is changed the least.

To regulate the size of the pencil of light that enters the camera a *diaphragm*, or *stop*, is placed in front of the lens. A large or small opening can be used. A small opening increases the sharpness of the picture, but the film or plate must be exposed for a longer time.

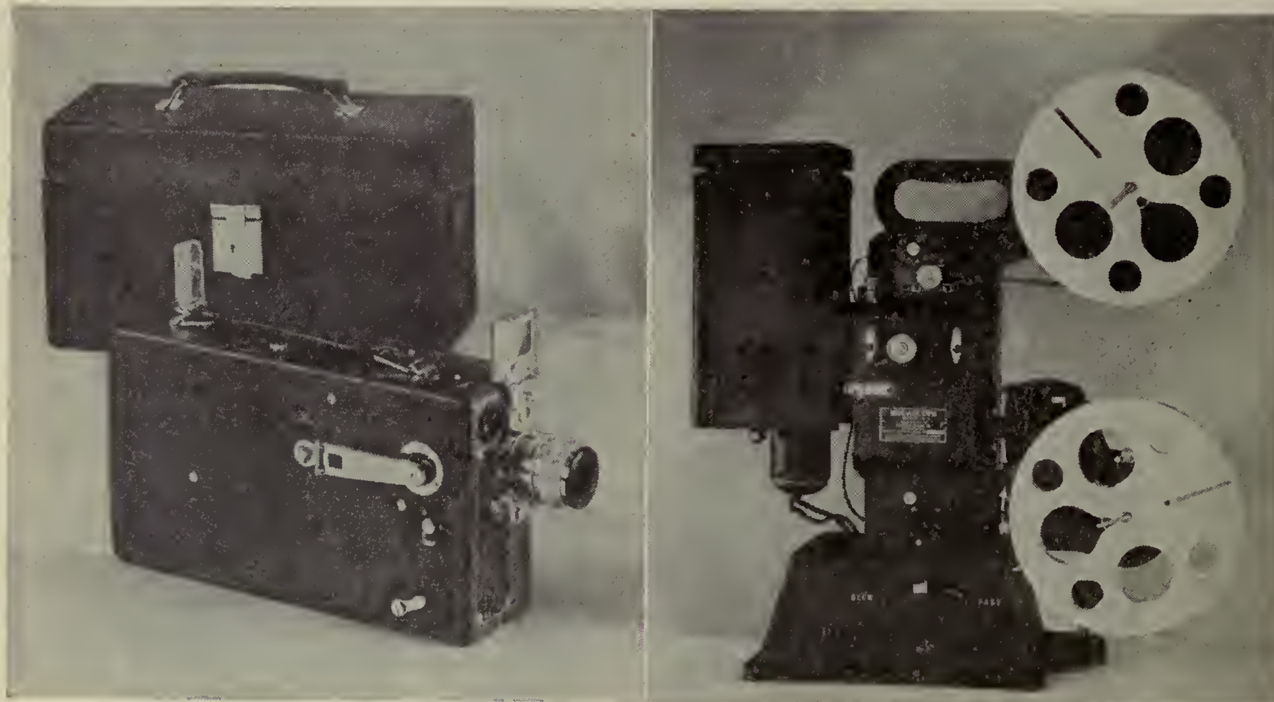
Cameras vary in cost from a dollar or two to hundreds of dollars. The chief difference between a cheap camera and an expensive one is in the lens. The ex-

Courtesy of Lightolier Company

FIG. 179. HOW TO USE LIGHT FOR THE PROTECTION OF THE EYES

pensive camera has a speedier lens. Only the central portion of the lens of a low-cost camera can be used to give a sharp image. The more costly cameras contain lenses that are so carefully ground that even if the diaphragm or stop is opened much wider, they produce sharp images. Thus the length of exposure is shortened.

Do moving pictures really move? Since it is possible to obtain small portable motion-picture projectors, many persons have become interested in amateur motion-picture photography. There is no essential difference between a motion-picture camera and a still camera except that in the former, pictures are taken automatically at the rate of sixteen per second on a long narrow film. The film is moved into place back of the lens by a spring and remains stationary $\frac{1}{32}$ of a second during exposure, after which another portion of the film comes into position for exposure. A negative is developed from the exposed film, and a positive print is made from the negative. The positive



Courtesy Eastman Kodak Co.

FIG 181. MOTION PICTURE CAMERA AND PROJECTION MACHINE FOR HOME USE

Courtesy Eastman Kodak Co.

FIG. 182. NEGATIVE AND POSITIVE "MOVIE" FILMS

film is run through a motion-picture projector while light passes through the film to a white screen, upon which images of the original objects photographed are produced.

It is interesting to know that what we speak of as motion pictures are in reality a series of still pictures. By certain mechanical arrangements in a motion picture projector one frame of the film is projected upon the screen at a time, each frame remaining stationary for about $\frac{1}{32}$ of a second. While a new frame is being moved into place a shutter covers the film. We do not observe any darkness on the screen during this time because of what is known as "persistence of vision." The retina of the eye holds an image a short while after the light producing the image no longer enters the eye. The appearance of successive pictures on the screen is so timed that the images formed on the retina merge into one another and the brain interprets them as if they were continuous.

What are some of the other optical instruments important to man? The microscope and telescope especially are being used daily by men of science to discover new information about our universe.

The microscope is used to study tiny objects that the human eye is unable to see alone. If a compound microscope is available in your school, examine it and get acquainted with the world of little things by viewing some of them through it. The simple compound microscope consists primarily of two convex lenses so arranged that one lens magnifies the image which the other one makes. In this way the image of a tiny object may be enlarged hundreds of times before it strikes the retina of the eye.

The telescope is used to study heavenly bodies such as stars and planets which are large but because of their great distances from us cannot be seen clearly by the naked eye. The *refracting telescope* consists essentially of a long hollow tube with a convex lens at each end. The large lens at the end of the telescope pointing toward the heavenly body collects the light and forms an image of the body in the hollow tube. The lens at the end we look through magnifies the image formed in the tube many times, depending upon the nature of the lens used. There is another kind of telescope called the *reflecting telescope*, which is made of a combination of mirrors and lenses.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 27
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 13

Courtesy of Bausch and Lomb Optical Company

FIG. 183. A SCIENTIST AT THE MICROSCOPE

Hunter and Whitman, *My Own Science Problems,* Unit 6; *Science in Our World of Progress,* Unit 6; *Science in Our Social Life,* Unit 6
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 21
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 15
Powers, Neuner, and Bruner, *This Changing World,* Chap. 20 (part); *Man's Control of His Environment,* Chap. 30
Skilling, *Tours through the World of Science,* Tour 13
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 8
Watkins and Bedell, *General Science for Today,* Chap. 22
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 1 (part)
Wood and Carpenter, *Our Environment: How We Use and Control It,* Unit 2, Topic 8

Special references

Eastman Kodak Company, *About Lenses*
Eastman Kodak Company, *How to Make Good Pictures*
Gray-Lloyd Manufacturing Co., *Lens Part of Photography*

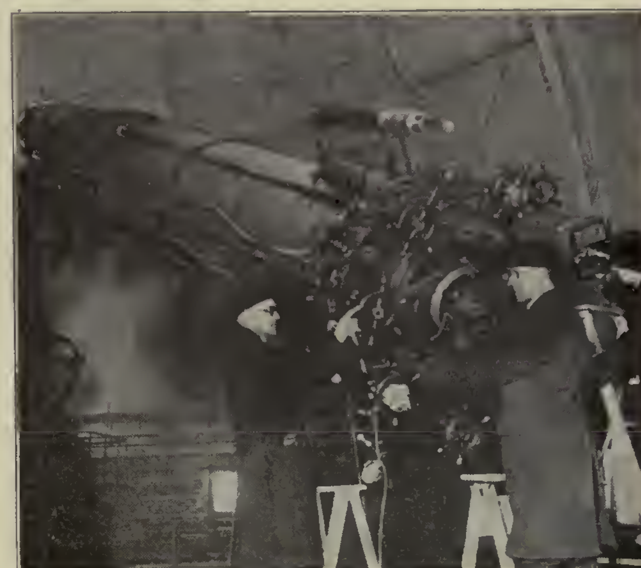
WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The work of the lens in optical instruments.
2. The structure of the eye.
3. How to care for the eye.
4. The common eye defects, their causes and remedies.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Make diagrams of concave and convex lenses and show how rays of light are bent in passing through each.



International News Photos, Inc.

FIG. 184. THE YERKES TELESCOPE

2. Name five instruments in which lenses are used.
3. A concave lens (converges, diverges) ____ light.
4. The lens in the human eye is a (convex, concave) ____ lens.
5. The distance from the ____ to the ____ of the lens is the focal length of the lens.
6. A ____ lens is used to correct farsightedness.
7. A ____ lens is used to correct nearsightedness.
8. What is the cause of nearsightedness?
9. What is the cause of farsightedness?
10. What is the cause of astigmatism?
11. What are the four essential parts of a camera?
12. Motion pictures are made possible because the ____ of the human eye holds an ____ of an object for a short time after the light producing the image ceases. This is known as the ____ of vision.
13. In a camera light enters through the ____ and strikes a ____ that has been made light sensitive with a ____ compound.

SUPPLEMENTARY MATERIALS

Reading suggestions

Abbot, *Everyday Mysteries* (Macmillan)
Carpenter, *How the World Is Housed* (American Book)
Forman, *Stories of Useful Inventions* (Century)
Lunt, *Everyday Electricity* (Macmillan)
Doubleday, *Stories of Inventors* (Doubleday)
Darrow, *The Boys' Own Book of Great Inventions* (Macmillan)
Luckiesh, *Seeing and Human Welfare* (Williams)
Collins, *Experimental Optics* (Appleton)
Bragg, *The Universe of Light* (Macmillan)

Gibson, *Photography and Its Mysteries* (Lippincott)

Eastman Kodak Company, *How to Make Good Pictures* (Eastman)

Broadhurst and Lerrigo, *Health Horizons*, section on "Light and Health" (Silver)

Reports which may be prepared

1. The early history of lighting
2. The history of electric lighting
3. The history of gas lighting
4. The lives and works of Sir Humphry Davy and Michael Faraday
5. Faraday's *Chemical History of a Candle*
6. The lighting system in your own home
7. The contributions of Thomas Edison to lighting
8. The proper care and use of one's eyes
9. The history and development of photography
10. The importance of color in modern life
11. The importance of light to health
12. The making of the mirror for the new 200-inch reflecting telescope

Great scientists you should know about

1. Sir Humphry Davy
2. Michael Faraday
3. Thomas Edison
4. Sir Isaac Newton

Investigations and things to do

1. Make a survey of the street lighting system in your own community.
2. Design and make a floor lamp provided with direct and indirect lighting systems.
3. Make a survey of the lighting conditions in your own home to locate conditions that may be improved.
4. Collect pictures of various types of lighting fixtures from catalogues, newspapers, and magazines and classify them as to whether they furnish direct, semi-direct, or indirect light.
5. Make a study of a motion-picture camera; also a motion-picture projector.
6. Investigate applications of mirrors and lenses in your own home.
7. Prepare a demonstration on how a camera works and how to develop and print pictures.
8. Take a pocket flashlight apart to find out how it works.
9. Demonstrate to the class how an acetylene bicycle lamp works.
10. Make a pinhole camera and take pictures with it.
11. Make a simple microscope.
12. Make a simple telescope using mailing tubes and lenses that fit them.
13. Make a scrapbook of advertising clippings that have to do with light.
14. Learn how to take, develop, and print pictures.

UNIT VI. THE RELATION OF HEAT TO HEALTH AND COMFORT

Heat is a form of energy upon which we depend for much of our everyday comfort and industry. Primitive man, in all probability, had to depend entirely upon the sun as his source of heat. When our remote ancestors discovered the value of fire an important step toward civilization was made, as modern ways of living and methods of industry require enormous quantities of energy, most of which is obtained by means of fire.

How or when fire was discovered is not known, but it is quite likely that the discovery was made in some accidental way. Early man's first acquaintance with fire may have been with a blazing forest set fire by a flash of lightning, or perhaps with the hot ash and lava erupted from volcanoes.

The effects of the discovery of fire on man's progress have been great. In fact, it is difficult to conceive how man could have emerged from a primitive state without fire.

There are other sources of heat besides fire which are in use today. Heat is obtained by friction, from other forms of chemical action than burning, and from electricity. The purpose of this unit is to acquaint you with the science of how heat is obtained, used, and controlled in everyday life. The use of clothing in relation to personal warmth will also be discussed.

How many of these things about heat do you know?

In your notebook answer as many of the questions as you can.

1. What do you think heat is?
2. What happens to wood or coal when it burns?
3. Why do people rub their hands together when they are cold?
4. Have you ever examined an electric iron or stove? What is inside of it?
5. Have you a thermometer in your home? For what is it used?
6. How many ways do you think there are for producing heat?
7. What kind of clothing do you wear in summer? In winter? How do they differ?
8. Have you ever seen or used a thermos bottle? What enables it to keep hot things hot or cold things cold?
9. What is the earth's most important source of heat energy?
10. Have you ever had occasion to remove stains from your clothing? How did you do it?
11. What kind of heating system do you have in your own home? How is it operated?

TOPIC 1. HOW HEAT IS PRODUCED

SUGGESTED PROBLEMS AND QUESTIONS

1. **What are the sources of heat energy for the earth?**
2. **What are the common fuels used to supply heat energy?**
3. **How are the common fuels which are used to supply heat energy on the earth obtained?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems and see if you are interested in them.

2. Plan your work throughout the unit so that you bring to bear upon the solution of each problem all the things you already know and new knowledge that you gain from your reading and investigations.

3. Make a thorough examination of some electric heating device used in your home.

4. The story of the formation of coal is very interesting. Get all the information about it you can from special reference books.

5. In the study of this topic the following new words may be met for the first time. Study them carefully and use them frequently.

insulator—a substance which is a poor conductor of heat or electricity.

kindling temperature—the temperature at which a substance starts burning.

oxidation—the combining of oxygen in the air with some other chemical element.

combustion—rapid oxidation with the giving off of heat and light.

fuel—a substance which burns readily, producing a large amount of heat at a relatively low cost.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 81. What is burning?

You learned about air and burning in Unit I. This completion exercise is for the purpose of recalling some of the important things which you learned at that time.

Ignite a wooden splint or a piece of paper; then complete the following exercise.

When a piece of wood burns, the elements ____ and ____, which are a part of wood, combine with ____ from the air

[1] See workbook, p. 42.

and form ____ and ____ vapor. Is anything lost in burning? Explain your answer.

Experiment 82. Does friction produce heat?

Rub the palms of your hands together vigorously. Do they become warm?

Rub the surfaces of two pieces of iron over each other for about a minute. Is there a change in temperature?

Why do we have to use oil in automobiles?

Why are ball bearings used in machinery?

Is the heat produced by friction in machines an advantage or disadvantage?

Do you know of any practical uses for heat produced by friction?

Experiment 83. Can heat be produced from chemical energy other than by burning?

Put some dilute hydrochloric acid in a test tube, and measure the temperature of the solution with a thermometer. Put some granulated zinc in the solution, and after the chemical action has gone on for about two minutes, measure the temperature of the solution again. Did a temperature change take place?

Pour several drops of strong sulphuric acid into a beaker of cold water. Feel the bottom and sides of the beaker. Has the water changed in temperature? Was there a transformation of chemical energy into heat energy in these experiments?

Activity 84. What do you know about fuels?

Make a chart showing the information you can find about various fuels. Divide your chart into three groups: solid fuels, liquid fuels, and gaseous fuels. Under each group heading write the names of fuels, where they are obtained, their use, and their cost.

Experiment 85. How may gas and coke be obtained from coal?

Secure a test tube and fit it with a one-hole rubber stopper carrying a glass tube as shown in Figure 185. Place a few lumps of soft coal in the test tube, place the stopper in the mouth of the tube, and heat in a Bunsen or alcohol flame. What comes from the tube? Will it burn? Can you find any evidence of tar in the tube? Examine the solid substance left in the tube. How does it differ from the original coal? This is coke. Record your results.

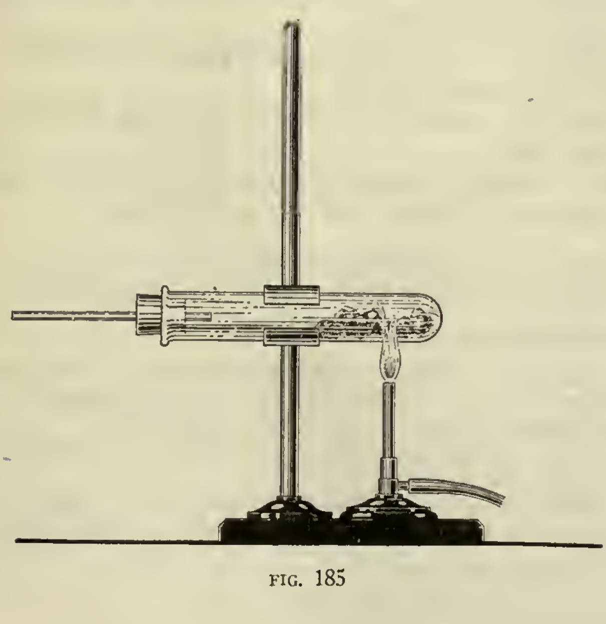


FIG. 185

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What are the sources of heat energy for the earth?

Heat energy is obtained from the sun. For hundreds of millions of years the sun has been sending vast quantities of heat through space to the earth, and scientists believe that it will continue to do so for many millions of years in the future. Scientists are trying to discover how this tremendous quantity of energy in the sun is produced and maintained, but as yet it is one of the unsolved mysteries of the universe. Without the sun's rays our earth would soon become a barren place, for plants and animals could not live long without the heat.

Heat energy is obtained from chemical action. Although the sun is our most important source of heat, we have not yet learned how to use the sun's rays directly to heat our homes and run our engines. A few solar engines have been invented, but none have proved economical to operate. We depend very largely on the heat obtained by burning coal, wood, oil, or gas. This heat comes indirectly from the sun because at some time in the past it was stored up by plants as chemical energy. Materials that burn are really reservoirs of energy that entered them from the sun, ofttimes thousands of years ago.

Burning is called *combustion.* What is combustion? You learned in your study of air that oxygen combines readily with many elements. This process, called oxidation, may go on slowly or rapidly. If oxidation is rapid enough to produce light and heat, it is called combustion.

During combustion chemical energy is converted into heat energy. If we make this combustion take place under a boiler of a steam engine, the steam formed can be harnessed and made to do work. In other words, we can convert heat energy into mechanical energy. One of the great principles of science is that *energy can be neither created nor destroyed.* This is called the *law of conservation of energy.* All man is able to do is to arrange conditions whereby he can control the conversion of one form of energy into another.

There are other ways of transforming chemical energy into heat energy besides combustion, but none are of practical importance, so far as heating the home is concerned. Several examples are given in the experiments at the beginning of the topic.

Electrical energy can be converted into heat. When

an electrical current passes through a substance that is a poor conductor, much of the electrical energy is changed to heat energy. Electricity is a very clean and convenient source of heat and is being used more extensively every day. In the home we have our electric cookers, toasters, coffee percolators, flatirons, and ranges. In some industries electric ovens and furnaces have entirely replaced the older combustion types.

Heat energy is obtained from friction and compression. We know from our everyday experiences that friction produces heat. When we saw a board, drill a hole, or hammer a nail, the tools become warm. We

Courtesy General Electric Company

FIG. 186. ELECTRIC RANGE

rub our hands together in order to warm them when we are outside on a cold day. A match is ignited by the heat produced when it is scratched over a rough surface. In each case mechanical energy is converted into heat energy.

Heat is also produced by compression. If you have ever pumped up a tire with an air pump you probably have noticed that the piston chamber becomes hot. Most of this heat is caused by the compression of the air. It has been discovered that the temperature inside the earth rises as we go toward the center at the rate of about one degree centigrade for every hundred feet depth. This heat is believed to be due to compression caused by the force of gravity.

What are the common fuels used to supply heat energy? Not all materials will burn, and because of this fact substances are classified as combustible and non-combustible materials. Fuels are materials that burn readily, producing large quantities of heat at relatively low cost. We are familiar with three general types of fuels classified by the state of matter in which they are commonly used as solid, liquid, or gas. The following table shows several of our common fuels classified in this manner.

FUELS

SOLID	LIQUID	GAS
Coal	Kerosene	Natural Gas
Wood	Crude Oil	Artificial Gas
Coke	Fuel Oil	Gasoline Vapors
Charcoal	Gasoline	
	Alcohol	

The heat energy of combustion comes from the uniting of elements in the fuel with oxygen from the air. Most of our common fuels contain the elements carbon and hydrogen, which unite with oxygen in the process of burning to form carbon dioxide in the one case and water vapor in the other.

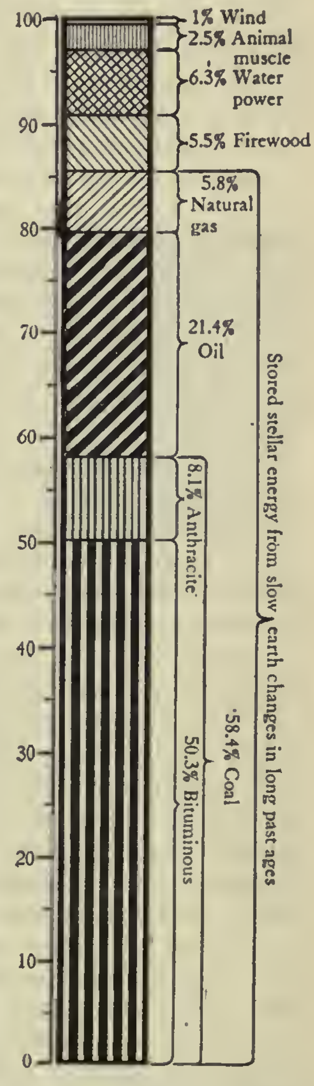


FIG. 187. SOURCES OF ENERGY IN THE UNITED STATES

Exercise. *Can you suggest a simple method of testing the last statement made in the paragraph above?*

Carbon dioxide and water vapor are known as products of combustion. Many fuels contains some elements or compounds that do not unite with oxygen. During the burning these useless substances are driven off into the air as gases or remain as ashes.

Exercise. *What are the chief energy sources in the United States? Carefully study the data shown in the graph, Figure 187, and find the answers to the following questions.*

What percentage of the energy available in this country is obtained from hard or anthracite coal.

What percentage from bituminous or soft coal?

What percentage from natural gas?

What percentage from oil?

What percentage from firewood?

Answer the following questions if you can.

Is water power connected in any way with heat energy? Explain.

Can you show how wind power and animal muscle power are derived from heat energy?

Scientists believe that all energy available on the earth comes either directly or indirectly from the sun. Can you trace all of the energy sources shown in the graph back to the sun? On the basis of the data shown in the graph, what conclusions can you reach concerning the sources of energy in the United States?

How are the common fuels used to supply heat energy on the earth obtained? Wood was formerly one of the chief sources of heat energy in America. In the pioneer days of this country wood supplied at least eighty per cent of the heat energy used. Even though other natural resources such as coal, gas, and oil are now used more extensively, wood still is an important source of heat energy. This is especially true in rural districts where the farm woodlot is still used to supply fuel for cooking and heating. In and near cities the chief use of firewood is for burning in fireplaces. Nearly one hundred million cords of firewood are still used annually in the United States.

As wood became scarcer, its cost increased, and other sources of heat energy were sought and developed. Another factor which has influenced the decline of wood as a fuel is the fact that other fuels give much more heat, pound for pound, than it does. For example, it requires nearly three pounds of wood to produce as much heat as can be obtained from one pound of anthracite coal.

Coal is our most common source of heat energy in this country. As you have learned from the study of the graph in Figure 187, coal supplies more than fifty-eight per cent of the heat energy used in this country. There are several reasons for this. Coal is relatively cheap as compared with other fuels, is easily accessible to most of the country, and requires a minimum of equipment to burn it. Oil and gas must have special burners attached to the furnace when they are used for house heating.

There are two principal types of coal used in this country, the soft or bituminous, and the hard or anthracite. Soft coal contains about fifty-four per cent carbon, forty per cent gaseous material, and five per cent moisture, while hard coal contains ninety-five per cent carbon, two per cent gaseous material, and three per cent moisture. The differences in the composition of the two types of coal is due to the changes which they have undergone in their formation.

Coal was formed millions of years ago from plants. Geologists, scientists who study rock formations, inform us that ages ago the climate in those parts of the earth where coal is now found was very warm and tropical. Also they believe that there was more carbon dioxide in the atmosphere than there is at present. Certain parts of the earth were low and swampy. As these conditions were ideal for plant life, giant ferns, mosses, grasses, and trees grew in abundance and flourished. As the plants in the swamps and low lying regions died, they fell into the water and were prevented from decaying. Do you know why? This process continued for centuries, producing thick layers of plant remains. It is believed that a sinking of the land followed and that everything was covered over with water and heavy layers of sand and clay that later hardened into rock. The pressure of the rocks, combined with heat and chemical action, changed the layers of plant remains into coal by driving out the gas and tar. As you have seen, soft coal contains a larger percentage of gases than hard coal, indicating that it was not subjected to extreme heat and pressure. Hard coal was probably formed from soft coal through the action of heat and pressure which forced out most of the gases and tar. Figure 188 shows the artist's conception, based on scientific evidence, of how a forest of the Carboniferous Period (the geological period when much of our coal was formed) might have appeared. Do the plants and animals shown resemble any of our modern forms?

American Museum of Nat. History
FIG. 188. A SCENE FROM THE COAL AGE

Coal occurs in nearly horizontal layers in the earth. In some places the deposits are so near the surface that the coal can be mined with steam shovels by a method known as "strip" mining. In other places shafts are sunk into the earth and galleries dug into the coal veins when they are reached. In still other places horizontal "drifts" are opened into the side of a mountain or hill to reach the coal vein. Figure 189 shows a man at work in a coal mine.

Figure 190 is a map of the principal coal areas of the United States.

Hard coal is used chiefly for house heating because it is a cleaner fuel than soft coal. However, most of our available heat energy in this country comes from soft coal because it is much more abundant and there-

fore much cheaper. Large quantities of soft coal are used annually in industry for generating power.

Coke is made from bituminous coal. In recent years coke has become a common fuel for home heating. It

Paul's Photos

FIG. 189. COAL MINER AT WORK

is obtained as a by-product in the manufacture of gas and other products from coal. Soft coal is heated away from air in large retorts, and after the gases and tarry substances have been driven off, coke remains in the retort. The gases and tarry substances are recovered, and from them many useful products are obtained. Figure 192 gives some idea of the variety of substances obtained from coal. Coke is a gray-black porous solid. It burns in a furnace with a very hot flame and is an efficient fuel, for there is very little ash or unburnable material in it.

Gas for fuel may be obtained from coal. As the coal is heated, gases which contain ammonia, coal tar vapors, and coal gas are driven off. In passing through the plant the ammonia is absorbed in the water, the tar is condensed, and other impurities such as sulphur are removed. The gas is then passed into the gas

FIG. 190. PRINCIPAL COAL AREAS OF THE UNITED STATES

holder, from which it may be delivered to the consumer directly or mixed with natural gas and then distributed.

Natural gas is also used for fuel. In certain parts of the United States gas is found in natural deposits in the earth. By drilling down to it we may obtain this gas and pipe it to cities where it is used for cooking, for heating, and for industrial purposes. The gas is frequently under such pressure in the well that it gushes out as soon as the cap rock which covers the deposit has been broken by the drill. It is often difficult to control these "gushers," and millions of cubic feet of gas are sometimes lost into the air before the well is capped. Also the gas may ignite, and serious damage may result from fire. In some cases the natural gas does not have sufficient pressure to force itself out of the well. It then is necessary to pump it from the well to the place where it is to be used.

Gas is usually sold at a certain rate per thousand cubic feet. At the place of use it is run through a meter which measures the amount consumed in cubic feet. Figure 191 shows a common gas meter.

St. Louis County Gas Co.

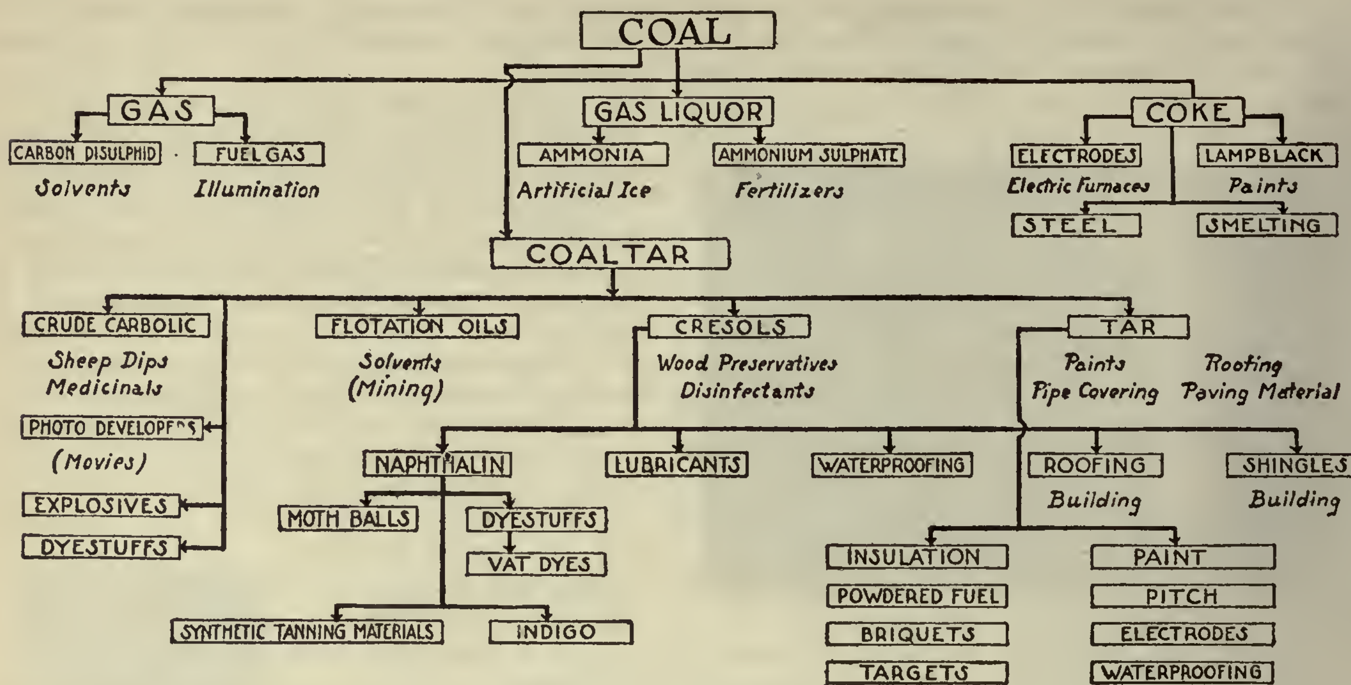
FIG. 191. GAS METER INSTALLED

Petroleum is used as a source of energy. You have learned from the study of the graph, Figure 187, that approximately twenty-one per cent of our available energy in this country comes from oil. Oil and other fuels are derived from petroleum which is obtained from natural deposits in the earth.

In recent years there has been a rapid increase in the use of oil both for home heating and for industrial purposes. Oil is also increasing as a fuel for railroads and for ships. While it is somewhat more expensive than coal, it is a much cleaner fuel and is much easier to handle and to store. Figure 215 shows an oil-burning furnace used for home heating.

Petroleum is secured in somewhat the same manner as natural gas. Wells are drilled down to the oil deposit, which is often found along with gas under great pressure. This may cause the oil to shoot out of the well with tremendous force; such a well is also known as a "gusher." In cases where the oil is not under pressure it is necessary, as in the case of natural gas, to pump it from the well.

Crude petroleum is a heavy, black, oily liquid which is a mixture of many substances. Besides the fuel oil that is obtained, it also contains gasoline, naphtha,



Courtesy National Research Council

FIG. 192. PRODUCTS DERIVED FROM COAL

International News Photo

FIG. 193. OIL WELL

kerosene, and other substances. These are separated from the petroleum by a process known as fractional distillation. In this process the crude petroleum is heated, and since the various substances which it contains have different boiling points, they are boiled off as the temperature of the crude petroleum is raised higher and higher. Figure 193 shows an oil gusher and Figure 194 a refining plant where the crude petroleum is separated into its parts by fractional distillation.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 11
Clement, Collister, and Thurston, *Our Surroundings*, Chaps. 7, 8
Hunter and Whitman, *My Own Science Problems*, Unit 5; *Science in Our World of Progress*, Unit 5
Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 19
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 9
Powers, Neuner, and Bruner, *The World around Us*, Chap. 19; *Man's Control of His Environment*, Chap. 27 (part)
Skilling, *Tours through the World of Science*, Tour 14
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 14
Watkins and Bedell, *General Science for Today*, Chap. 19
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 1 (part)
Wood and Carpenter, *Our Environment: Its Relation to Us*, Chap. 11; *Our Environment: How We Use and Control It*, Unit 2, Topic 7

Courtesy Shell Petroleum Corporation

FIG. 194. OIL REFINERY

Special references

Butler, *Household Physics*
Lynde, *Physics of the Household*
Black and Davis, *Practical Physics*
Ashmead, *The Man Who Mines Our Coal* (*Scientific American*, May 18, 1918)
Fraser, *Secrets of the Earth*
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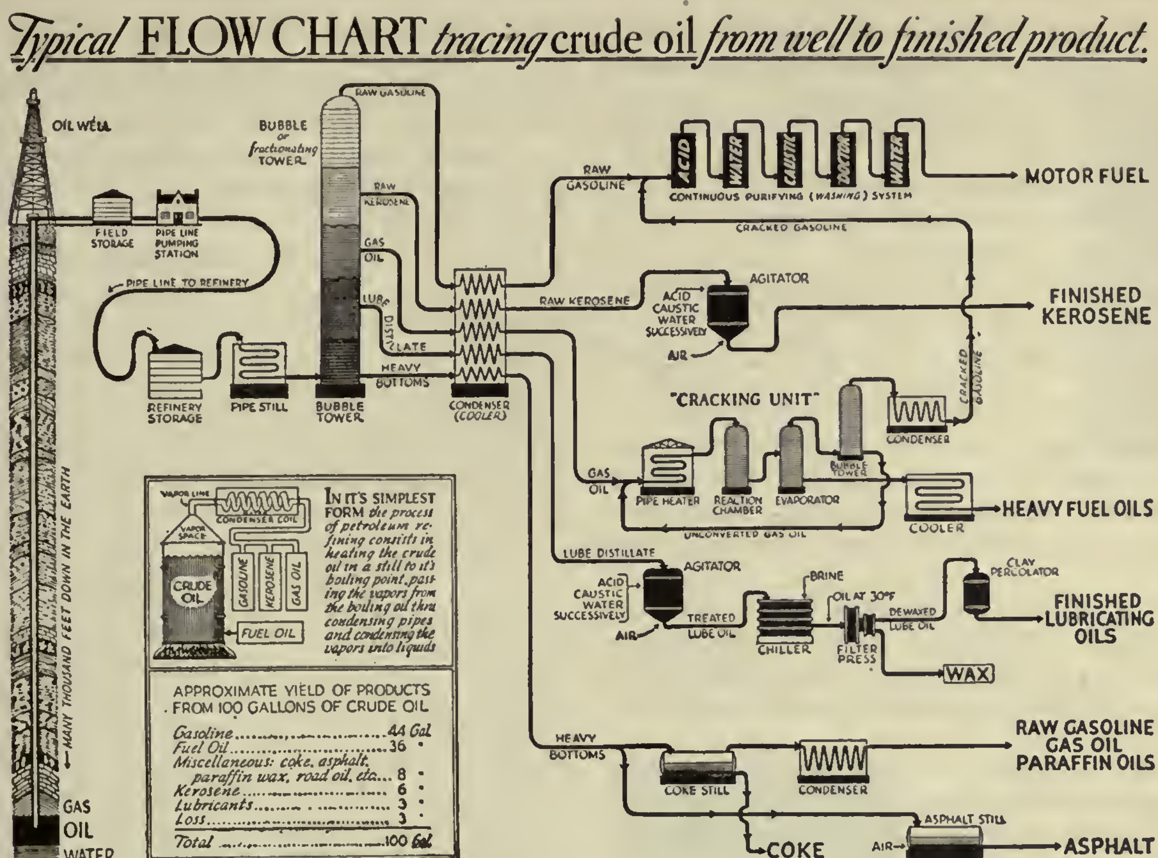
WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the chemical changes that take place when a substance burns.



Courtesy American Petroleum Institute

FIG. 195. DIAGRAMATIC SCHEME OF PETROLEUM REFINING

2. A knowledge of the various ways by which heat can be produced.
3. A knowledge of various types of fuels, their relative costs and uses.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Make a list of the most commonly used fuels.
2. The two principal elements in fuels are ____.
3. The principal element in coal is ____.
4. Coal was formed from ____.
5. Rapid oxidation which produces noticeable heat and light is called ____.
6. The most important source of heat energy on the earth is ____.
7. Give some examples of producing heat by friction.
8. Most of our coal in the United States is mined in ____.
9. The chief products of combustion are ____ and ____.
10. How does anthracite coal differ from bituminous coal?
11. What are some of the substances other than fuels that are secured from coal?
12. How is coke obtained commercially?
13. How much more efficient is anthracite coal than wood as a fuel?
14. Make a list of the common fuels in the order that you would select them for heating your home if cost were not a consideration.
15. Make a diagram of a coal gas plant. Label all the parts.
16. Explain how petroleum is secured from the earth.
17. Make a list of some of the substances other than fuel oil that are secured from petroleum.
18. The process by which gasoline, kerosene, and other substances are separated from petroleum is known as ____. It is made possible because these substances all have different ____ points.
19. In the coal-gas plant, ____ is removed by the water.
20. What type of fuel supplies most of our heat energy in the United States?

TOPIC 2. HOW HEAT AND TEMPERATURE ARE MEASURED

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is heat?**
2. **How is temperature measured?**
3. **How are thermometers constructed?**
4. **How do we measure heat?**
5. **Do substances vary in their ability to absorb heat?**

SUGGESTIONS AND HELPS FOR STUDY

1. Read carefully the problems listed above, and see if you understand them before you begin to work.

2. Heat and temperature are not the same. Make certain that you know the correct meaning of each term.

3. In connection with problems 2 and 3, secure a centigrade and a Fahrenheit thermometer from your instructor. Place them side by side and make diagrams showing a comparison of the two scales. See Experiment 88.

4. You will find the following words in the study of this topic. If they are new to you, study them carefully and use them as often as possible in order that they may become a part of your vocabulary.

expand—to become larger.
contract—to become smaller.
Calorie—amount of heat required to raise one kilogram of water one degree centigrade. This is known as the "great" or kilogram Calorie. It is always spelled with a capital *C*.
calorie—the amount of heat required to raise the temperature of one gram of water one degree centigrade. This is known as the gram calorie and is always spelled with a small *c*.
kilogram—1000 grams.
ounce—about 28.4 grams.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 86. Is heat a substance having weight?

Secure a metal ball and weigh it on a good balance. Heat a jar of water to boiling and measure the temperature of the water with a thermometer. Heat the ball by immersing it in the hot water. Weigh the ball again on the balance. Did the metal ball gain in weight when it was heated? Is heat a substance? Find a definition of heat.

Experiment 87. Can we tell temperature accurately by touch?

Heat water in a large vessel until it is comfortably warm. Divide the water in two pans. Hold one hand in very cold water and the other in warm water for several minutes. Quickly put one hand in each pan of water. Does the water feel at the same temperature to both hands? Is your sense of temperature reliable? Why do doctors use a thermometer in determining the temperature of a patient instead of touching the patient's head or arms?

Experiment 88. How is a thermometer constructed?

Obtain a Fahrenheit and a centigrade thermometer to compare them. How are they made? What liquid is used in the bulb. How do you hold the thermometer when reading it? What is the boiling point of water on each thermometer? What is the freezing point of water? Put the bulbs of the thermometers in cold water and take temperature readings. Then put the bulbs of the thermometers in hot water. Take the readings again. Why do the columns of liquid move? Make drawings of the scales.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is heat? Man was puzzled for many centuries as to whether heat is matter or energy. Until about a century ago heat was thought of as a substance and was spoken of as such under the name of "caloric." Heat was considered as matter just as we think today of air, water, and metals as matter or substances.

A simple experiment is suggested at the beginning of this topic through which you can determine whether heat is matter or a form of energy. If a cool

FIG. 196. DIFFERENCE BETWEEN HEAT AND TEMPERATURE

metal ball is weighed, then heated and weighed again, its weight remains the same. If heat were a substance, since all substances have weight, the ball should gain weight as it becomes hotter. Since the ball did not gain in weight after it was heated, we conclude that heat is not matter. It is true that the metal ball increased in size, for nearly all substances expand when they are heated, but its weight remained the same.

Heat, therefore, is a form of energy. Scientists now believe that heat is a rapid motion of molecules. The hotter a substance is, the faster its molecules are

[1] See workbook, p. 44.

moving. As a body is cooled the molecules move more slowly.

Heat also exists as a form of radiant energy. Hot bodies send out waves of heat by radiation. These waves travel very swiftly through a vacuum, that is, through space without matter in it. In order to explain this phenomenon scientists have imagined that all space, even that between molecules of matter, is filled with some weightless, elastic fluid which is called ether. It is imagined further that the rapidly moving molecules of a hot body disturb this ether. This disturbance passes through the ether, in the form of a wave, at the tremendous speed of 186,264 miles per second. Thus radiant heat energy may be defined as a *wave motion in ether.*

Heat and temperature are not the same. Heat is an invisible form of energy; hence we must study it from the effects which it produces on various substances. In everyday life and in science we commonly measure the temperature of materials and speak of them as hot or cold. It is important to know, however, that temperature is a measurement of intensity of heat and not quantity of heat. A cup full of water may be at the same temperature as a barrel full of water, but the barrel of water will contain much more heat. This fact may be stated in another way: the water in the cup and the water in the barrel have the same degree of intensity of heat; but the barrel of water contains a greater quantity of heat because the total energy of moving molecules is greater, as there are many more of them in the barrel. Also a cup of boiling water would contain less heat than a barrel of water at a lower temperature, even though the temperature or intensity of heat in the cup is greater. To measure heat or temperature, then, consists of measuring two different aspects of heat energy.

How is temperature measured? Temperature is measured by means of an instrument called a thermometer. The first thermometer was made by Galileo, a great Italian scientist, in 1592. It consisted of a bulb of air (see Fig. 197) connected with a glass tube, the end of which dipped into a container of water. This type of thermometer did not prove very satisfactory because the air inside it was affected by changes in air pressure as well as by changes in temperature. A few years later Galileo made a different thermometer by placing alcohol in a sealed tube.

Before the time of Galileo temperature could be judged only through the sense of touch. This, as you know from experience, is extremely unreliable. On entering a house on a cold day we may think the house is very warm. After being in the house a while we may then think it is cool, whereas the temperature indoors may not have changed a single degree. To be scientific about temperature changes we now make accurate measurements with carefully constructed thermometers.

Fisher Scientific Co.

FIG. 197. GALILEO'S AIR THERMOMETER

How are thermometers constructed? As both centigrade and Fahrenheit thermometers are in use in America, it is well to understand both. They are glass tubes containing mercury or colored alcohol. Above the liquid in the tube is a vacuum. When the temperature rises the liquid expands and the expansion is measured by the change in length. When the temperature falls the liquid contracts.

Modern thermometers are marked off in degrees in the following manner: the bulb of the thermometer is placed in melting ice, and the point at which the mercury or alcohol in the tube stops is called the *freezing point.* Then the bulb is placed in steam escaping from boiling water, and the point at which the mercury or alcohol stops is marked the *boiling point.* The difference between the Fahrenheit and centigrade thermometers is that different numbers are used to express the degrees of temperature represented by the boiling point and freezing point of water. On the Fahrenheit scale the boiling point of water is 212° and the freezing point of water is 32°. On the centigrade scale the boiling point of water is 100° and the freezing point of water is 0°. Thus 100 degrees on the centigrade scale equal 180 on the Fahrenheit scale, or in other words one degree centigrade equals $\frac{180}{100}$ or $\frac{9}{5}$ of a Fahrenheit degree.

FIG. 198. EARLY FLORENTINE THERMOMETERS

Study Figure 200 carefully; learn how to compare the two scales and how to transpose one to the other.

The centigrade thermometer is the more convenient to use and is preferred by scientists. For measuring temperature changes in public places the Fahrenheit thermometer is still widely used in this country.

Heat affects substances in different ways. When a substance is heated, that is, when heat energy is added to it, the results may be different. For example, when ice is heated it melts, but its temperature does not change until all of the ice has turned to a liquid. On

the other hand, if water is heated its temperature begins at once to rise, and if it is heated long enough it will boil and turn to steam. Another interesting thing which happens to bodies when heated is a change of size. When a metal bar is heated it increases in length and in volume. This is known as expansion. You no doubt have observed that telephone and telegraph wires sag in the summer and are taut in the winter. This again is the result of expansion.

How do we measure heat? When we buy fuels to heat our homes we should be interested in knowing how much heat we get for our money. Ordinarily not all of the substance in a fuel is converted into heat energy. Ash may be present or there may be material which escapes as unburned gas.

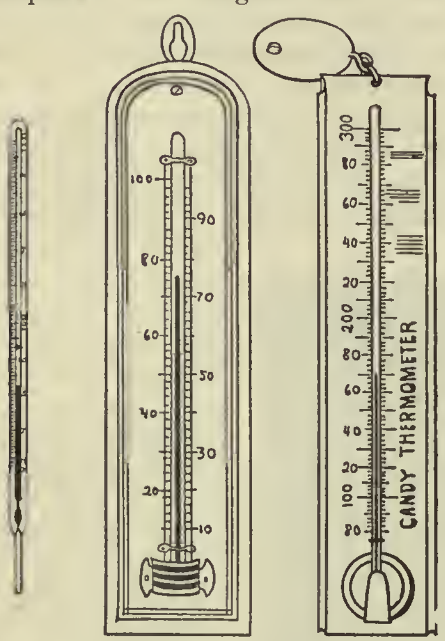


FIG. 199. FEVER, HOUSEHOLD, AND CANDY THERMOMETERS

Since heat is a form of energy and not a substance, it cannot be measured directly in pounds or grams. It must be measured by the effects it produces. The unit of measurement of the heat value of fuels in this country is the "British thermal unit"; it is written B. T. U. It is the amount of heat required to raise one pound of water one degree Fahrenheit. The heat values of our common fuels, expressed in Calories per pound and British thermal units per pound, are given below.

	CALORIES PER POUND	B. T. U. PER POUND
Coal (hard)	3400 to 3700	13,500 to 15,300
Coal (soft)	3000 to 3600	11,700 to 14,400
Wood (oak)	2100	8316
Charcoal	3227	12,780
Petroleum	About 5000	About 20,000

In European countries and in our own scientific laboratories the *Calorie* is the unit of measurement of heat. A Calorie is the amount of heat required to raise one kilogram of water one degree centigrade. This means that a kilogram of water rising one degree centigrade takes in one Calorie of heat, while a kilogram of water cooling one degree centigrade loses one Calorie of heat.

Do substances vary in their ability to absorb heat? It is an interesting fact that various materials differ greatly in their capacity to absorb heat. A kettle of water on a stove will not heat as quickly as a piece of

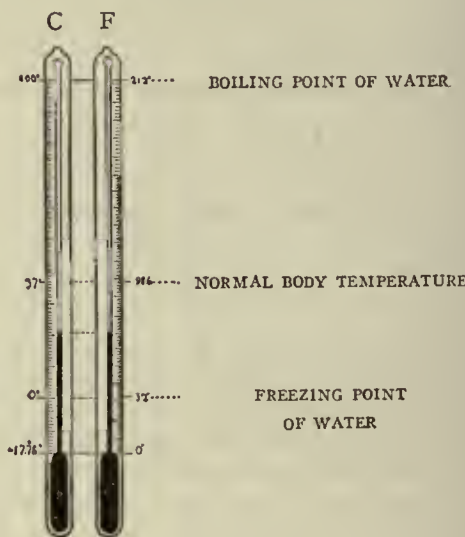


FIG. 200

iron of the same weight. Experiments show that water, per unit of weight, requires more heat to raise its temperature one degree than any other common substance. Also it cools more slowly than other substances because it has more heat to lose. The amount of heat that will raise one gram of water one degree centigrade will raise one gram of iron about ten degrees centigrade, one gram of silver twenty degrees centigrade, and one gram of lead about thirty-three degrees centigrade.

REFERENCES FOR FURTHER STUDY

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Caldwell and Curtis, *Science for Today*, Chap. 12

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WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A concept of heat as a form of energy.
2. A knowledge of the construction and uses of Fahrenheit and centigrade thermometers.
3. Skill in making measurements with thermometers.
4. A knowledge of how quantities of heat are measured.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The temperature of a body is measured in ____; the quantity of heat a body contains is measured in ____ or ____.

2. Heat is a form of ____.

3. The boiling point of water on a centigrade thermometer is ____; its freezing point is at ____ degrees.

4. One degree on a centigrade thermometer is equal to ____ degrees on a Fahrenheit thermometer.

5. The boiling point of water on a Fahrenheit thermometer is ____; its freezing point on the same thermometer is ____.

6. Two liquids commonly used in thermometers are ____ and ____.

7. The ____ thermometer is most commonly used in scientific work.

8. To raise two kilograms of water 5° C. would require ____ Calories.

9. Write a paragraph on the importance of a knowledge of heat values of various fuels.

TOPIC 3. DEVICES USED FOR HEATING

SUGGESTED PROBLEMS AND QUESTIONS

1. **How is heat transferred from place to place?**
2. **What are some of the earlier methods of heating the home?**
3. **How is a home heated by means of a hot-air furnace?**
   What are the advantages and disadvantages of this method of heating?
4. **How is a home heated by means of a hot-water heating plant?**
   What are the advantages and disadvantages of a hot-water heating plant?
5. **How is a home heated by means of a steam heating plant?**
6. **What is air conditioning?**

SUGGESTIONS AND HELPS FOR STUDY

1. Become thoroughly familiar with the problems listed above before you begin your study.

2. Get all the experience you can with the various types of heating plants mentioned in this study. Examine them first hand if possible.

3. Make diagrams of the heating systems mentioned in problems 3, 4, and 5. Label all the parts neatly.

4. The following words are new. Study them carefully and use them as often as possible in connection with your work so that they will become a part of your vocabulary.

molecule—the smallest bit of a substance that can exist alone as such.

vibrate—to move to and fro.

conduction—movement of heat from molecule to molecule.

convection—movement of heat by aid of currents.

radiation—movement of heat by ether waves without the aid of matter.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 89. How is heat radiated from a hot body?

Fill a shiny tin can with boiling water. Bring the palm of your hand toward the sides of the can and note the effects. Repeat the process from all sides and the bottom of the can. Place some cardboard around the can and repeat the observations. If you have hot-water or steam radiators in your home, see whether heat is sent off in all directions from one of them. Does the can send off heat in all directions? What is this method of heat transference called?

Experiment 90. How does heat travel by conduction?

Secure rods several inches long made of different metals. Mount them on a board as shown in Figure 201. Put a small piece of wax on the far end of each metal rod. Hold the other ends of the rods in a flame and note the order in which the pieces of wax melt. How does heat get from one end of a metal rod to the other end? List the metals tested in the order of their ability to conduct heat. Define conduction.

[1] See workbook, p. 45.

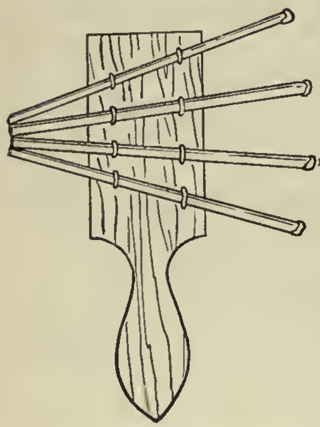


FIG. 201

Experiment 91. What is convection?

Put a small amount of fine sawdust into a beaker full of water. After some of the sawdust has settled to the bottom, apply heat along one side of the beaker. Observe what happens to the sawdust. Place the bulb of a thermometer just below the surface of the water and read the temperature from time to time.

Describe convection as a mode of transmission of heat.

Experiment 92. Is water a good conductor of heat?

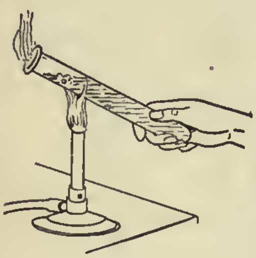


FIG. 202

Fill a large test tube about three-fourths full of cold water. Grasp the lower end of the test tube and hold the upper end in a hot flame as shown in Figure 202. Are you able to boil the water in the upper part of the test tube while the lower end is cool enough to hold in your hand? Is water a good conductor of heat? Is glass a good conductor of heat? Poor conductors are called insulators. Do you know of any other substances that are good insulators?

Experiment 93. How does a hot-water heating system work?

Set up the apparatus as shown in Figure 203. The radiators may be made from half-pint milk bottles, and a flask made from a burned-out electric light globe may be used for a boiler if other equipment is not available. If T tubes are not at hand, the system may be set up with a single radiator. The expansion tank should be placed at a level higher than any other part.

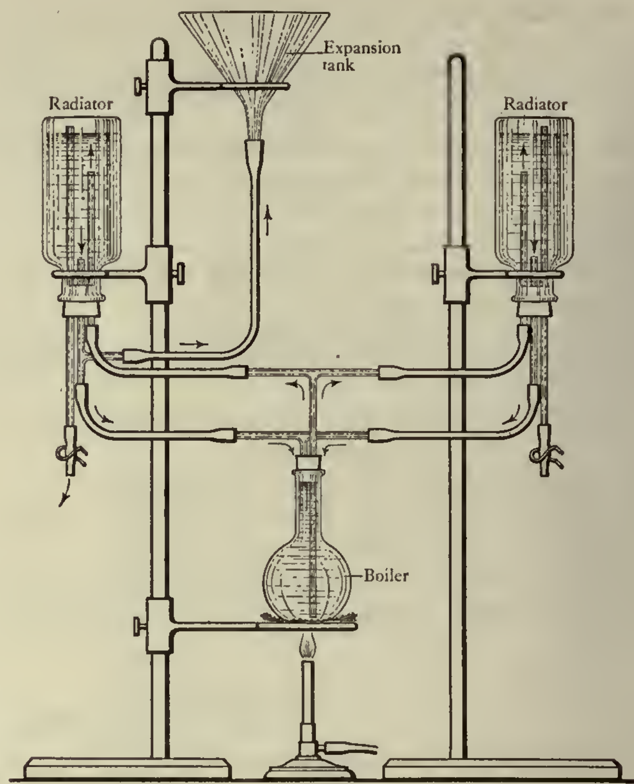


FIG. 203

After heating for a short time, observe any flow through the system. Try to answer these questions. What part of the radiators heats first? On the basis of Experiment 91, can you establish a possible cause for the circulation of the water in the system? Can you suggest an experiment to test this point further? Why is the expansion tank important? Record your results.

The ____ part of the radiators heats first. This would seem to indicate that ____ water is heavier than ____ water. How might this be tested further? The circulation of the water in a hot-water system is caused by ____ currents. In a hot-water heating system the hot-water pipe should leave the furnace near the ____ and the return or cold-water pipe should enter near the ____ of the furnace.

Experiment 94. How does a steam heating system work?

Set up the apparatus as indicated in Figure 204. Half-pint milk bottles may be used for radiators and a boiler may be made from an old electric light bulb if other equipment is not at hand. Glass T tubes may be secured from any apparatus supply company. This experiment may be set up with a single radiator. It is important to have the glass tubes slope as shown in the illustration and to have one radiator open. The boiler should be about half full of water. This water must be boiling to supply the necessary

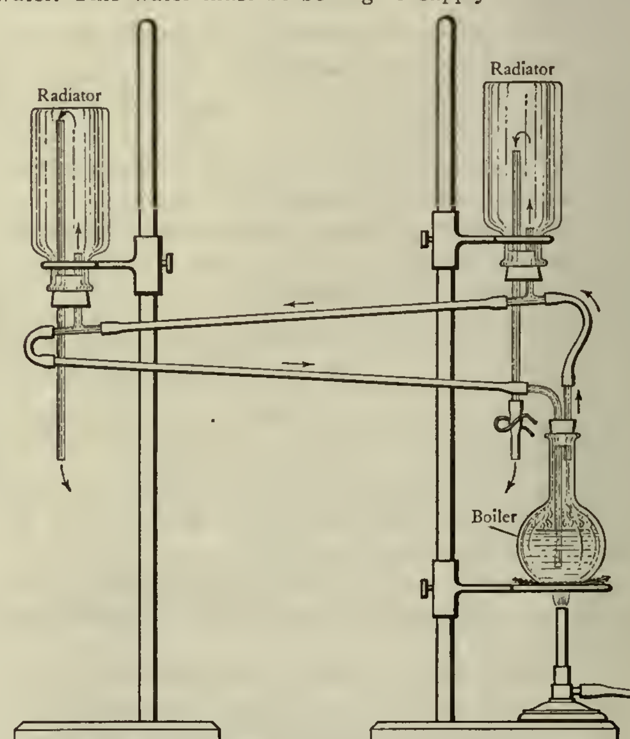


FIG. 204

steam. What physical change takes place in the boiler? What is this change called? Does it absorb or give out heat energy? What physical change takes place in the radiators? What is this change called? Does it absorb or give out heat energy?

In the boiler, water is changed to ____ and heat is (absorbed, given out) ____. In the radiator, ____ is changed to ____. This process is known as ____, and heat is (absorbed, given out) ____ as it goes on.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How is heat transferred from place to place? In the first topic of this unit we were concerned chiefly with a study of how heat energy is produced. We will now be interested in learning how heat may be conserved, controlled, and transmitted. In fact, a clear understanding of how to conserve heat depends upon a study of the ways of transmitting heat. In general we may say that there are three different methods of heat transmission. They are called conduction, convection, and radiation.

Conduction. Heat always tends to pass from warmer objects to cooler objects that are in contact with them or from one end of an object to the other when one end is warmer than the other. Everyone has experienced this in everyday life. The handle of a silver teaspoon placed in a cup of hot cocoa or coffee soon becomes warm. When one end of an iron poker is held in a fire the other end becomes heated by the flowing of heat energy from the fire through the metal. *The passing of heat through these substances from molecule to molecule is called conduction.* It is explained in the following manner. The molecules of all substances are continually vibrating. The silver teaspoon in the hot liquid or the iron poker in the fire is raised in temperature; this really means that the molecules are vibrating at a greater rate of speed. These more rapidly moving molecules bump against those next to them, making them vibrate faster. In this way the increased molecular motion is transmitted to the other end of the metal and produces the rise in temperature.

Substances vary greatly in their ability to conduct heat. Some conduct heat quickly while others resist the flow of heat. In general, metals are better conductors than any other substances. Solids as a class are better conductors than liquids, while liquids are better conductors than gases.

Light and porous substances such as felt, cork, and asbestos are poor conductors. In fact, most of our best insulating materials are porous. This is due to the fact that most of their bulk is air, which is one of the best insulating materials known. Heat travels through a piece of aluminum nearly ten thousand times as readily as it passes through air. The following table gives lists of good, fair, and poor conductors. Study them carefully; perhaps you can add other substances to the lists.

GOOD CONDUCTORS	FAIR CONDUCTORS	POOR CONDUCTORS
Silver	Ice	Asbestos
Copper	Water	Air
Iron	Brick	Wood
Tin	Plaster	Paper
Aluminum	Granite	Silk
Brass	Glass	Wool
Zinc		Cotton
		Linen

Convection. If you have studied the topic of weather you are perhaps familiar with the fact that heat travels in currents by convection. These currents, you will recall, are set up in gases or liquids because of a difference in temperature. The heated gas or liquid expands and becomes less dense than the substance around it. The lighter gas or liquid as a result is then forced upward by the heavier matter, thus forming currents. In this manner heat is distributed, the heated particles themselves moving in the form of currents. We shall find that convection plays an important part in several of the heating systems employed in heating our homes.

Radiation. Transmission of heat by conduction and convection requires the presence of matter. Hot bodies, however, also radiate heat, that is, they send out waves of heat in straight lines which are able to pass through a perfect vacuum.

The heat we receive from the sun comes to us by radiation. These radiant waves travel across the 93,000,000 miles of intervening space at the enormous speed of 186,264 miles per second.

Radiant heat waves are peculiar in that they pass through some substances such as air and glass without heating them to any appreciable extent. These substances are transparent to radiant heat waves. When heat waves strike a substance through which they cannot pass, they make the molecules in the substance vibrate faster, thus raising the temperature of the matter.

It has been found by experiment that substances with rough surfaces absorb the radiant heat better than substances with smooth or polished surfaces. In general, good absorbers are good radiators, and poor absorbers are poor radiators. Also dark-colored substances are better absorbers of heat than light-colored objects. Why is the thermos bottle silvered inside and out? Why does it have a vacuum space between its walls? How does it keep hot things hot and cold things cold?

What are some of the earlier methods of heating the home? The problem of how better to heat and ventilate the home has occupied the attention of mankind

for many years. It is quite likely that primitive man lived in caves that were heated with open fires. Doubtless he had to contend with much smoke and many odors. The American Indian built a fire on the floor of his wigwam, and the smoke escaped through a hole at the top. The building of a fireplace into the wall of a house with a chimney attached to remove the smoke and gases marked an important step forward in heating which led finally to the invention of modern stoves and furnaces.

The fireplace has been in use for centuries. It adds cheer and comfort to the living room of modern homes, and because of its increasing use must be considered a modern home heating device as well as an old one. It has some decided disadvantages, however, that should be considered. It is a very uneconomical heating device because much of the fuel is wasted,

FIG. 205. COLONIAL FIREPLACE

most of the heat being carried up the chimney by convection currents. Since the heated air passes up the chimney and since air is a poor conductor of heat, the heating of the room is done mainly by radiation. This results in very uneven heating. Near the fire it is too hot for comfort and some distance away it is too cool.

Probably the principal advantage of the fireplace lies in the fact that it insures good ventilation. Good air flows into the house around the windows and doors. As the currents of air inside the house are toward the fire, the stale air is rapidly removed through the chimney.

Stoves have been in use for about two centuries. The first stoves were merely iron boxes with a door at one end and an opening in the top for smoke to escape. Later Benjamin Franklin invented what is known as the Franklin stove (Fig. 206). It consisted at first of a small open box of iron that was placed inside a fireplace. It was built so that part of the iron box extended into the room. This made for greater efficiency in heating for two reasons: the heated iron radiated heat better than brick or stone, and layers of air next to the iron, extending into the room, were heated and set up convection currents in the room. Thus less heat escaped through the chimney.

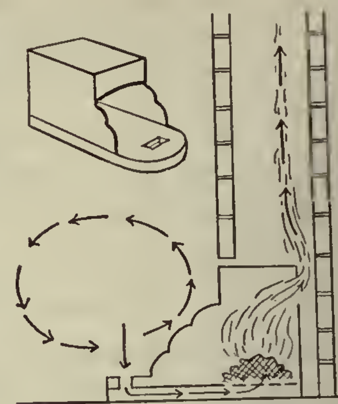


FIG. 206. FRANKLIN STOVE

The modern stove is a greatly improved device. It consists of a stove inside a steel jacket (see Fig. 207). The air between the stove and the jacket is heated by the burning fuel in the stove. Convection currents which are set up heat the room. Heat energy is also radiated from the stove.

The rate of burning in the modern stove is controlled by three drafts and a smoke-pipe damper (see Fig. 207). When making fire we open the lower draft and the smoke-pipe damper and close the other two drafts. This provides for the largest amount of air possible to pass through the fuel. After the fire is burning well, the lower draft and the chimney damper are closed. This decreases the amount of air passing through the fire. The hot blast draft is opened next; this permits air to enter the fire pot above the burning fuel. This provides for better burning of combustible gases and carbon particles which otherwise would

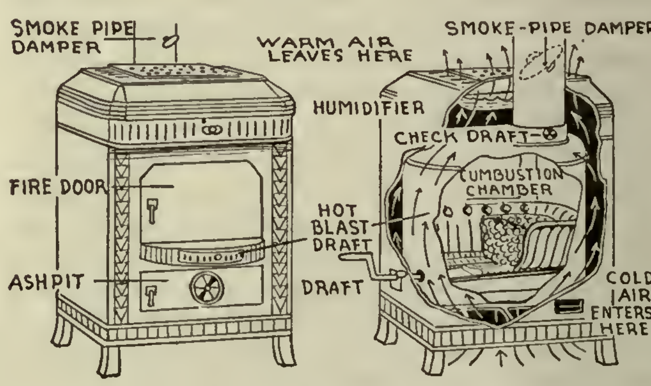


FIG. 207. MODERN STOVE

form smoke and soot. If a slower rate of burning is desired, the check draft is opened. Can you figure out why opening the check draft decreases the rate of combustion?

How is a home heated by means of a hot-air furnace? Although hot-air furnaces are placed in the basement, they operate on the same principles as the modern stove just described. There are two different types: the pipeless hot-air furnace (Fig. 208), which has a single register through which convection cur-

rents enter and leave the furnace, and the type with pipes (Fig. 210) conducting the heated air to the various rooms in the house. The pipeless furnace is the cheaper to install.

The chief advantages of the hot-air furnace are the low cost of installation, the ease with which it can be adjusted to sudden changes in temperature on the outside, and the combination of heating and ventilation which it furnishes. Its chief disadvantages are the difficulty, often encountered, of heating the windward side of the house, leakage of gases and smoke into the air supply, and the cost of operation. Some of these disadvantages can be overcome if painstaking attention and study are given to the installation of the furnace.

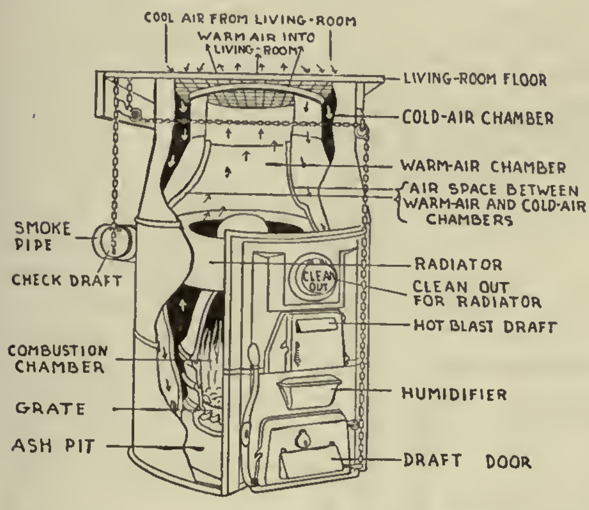


FIG. 208 PIPELESS FURNACE

How is a home heated by means of a hot-water heating plant? In this type of heating plant (Fig. 211) the heat of combustion is applied to water in the furnace which is carried by convection currents through pipes to radiators in various rooms of the house. The radiators absorb some of the heat from the water and in turn heat the layers of air next to them, setting in motion air convection currents. Part of the heat is also radiated through the room; however, it is by convection currents that the room is heated evenly. The hot-water heating plant is more efficient than a hot-air furnace and it maintains a more even temperature. It is more expensive to install, however, and it is slow to heat.

How is a home heated by means of a steam heating plant? The parts of a steam heating plant (see Fig. 212) look very much like the parts of a hot-water system. They differ considerably, however, in operation. In the steam heating system the boiler is only partly filled with water, which is converted into steam by the fire. As steam forms in the boiler, the pressure that is created is sufficient to force the steam through steam pipes to the radiators. In the radiators the steam condenses to water. As much heat is given to the radiators as was required to convert the water to steam in the boiler of the furnace. The radiators in turn heat the room by convection and radiation. The condensed water in the radiators returns to the boiler to be changed again to steam.

A steam heating system costs less to install than a hot-water system and gives more heat in proportion to the amount of fuel burned. As with the hot-water system, it provides no means of ventilation for the house. Therefore fresh air must be supplied through windows and doors or by some special entrance provided in the building. Steam heating systems are used very successfully in heating large buildings or in heating groups of buildings by a central heating plant because steam can be more successfully transported long distances than can hot water or hot air.

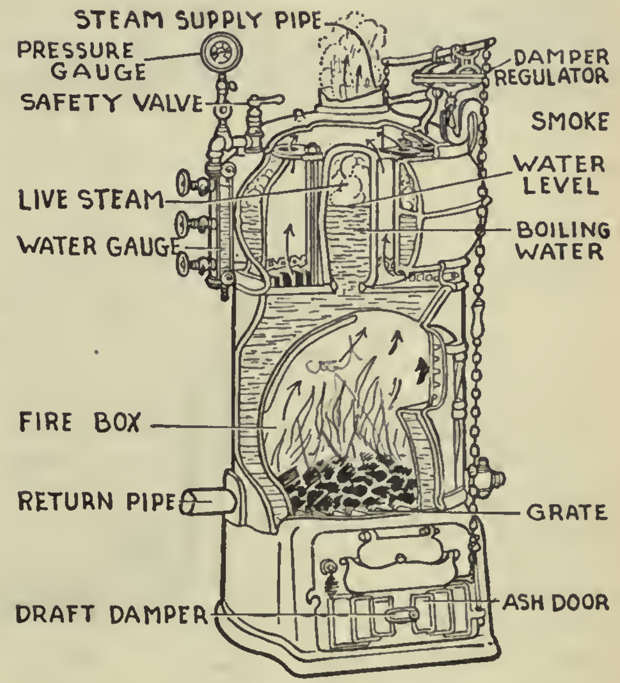


FIG. 209. BOILER OF STEAM HEATING SYSTEM

Oil burners which are attached to furnaces have been gaining in popularity in recent years. They are clean and efficient heating devices, producing an even and automatically controlled heat.

In sections of the United States where natural gas is abundant, gas jets automatically controlled are sometimes used in the furnace. This method provides clean and efficient heating, but in most communities it is more expensive than oil or coal.

Electric heaters and ranges are probably the most convenient and cleanest of all heating devices, but the

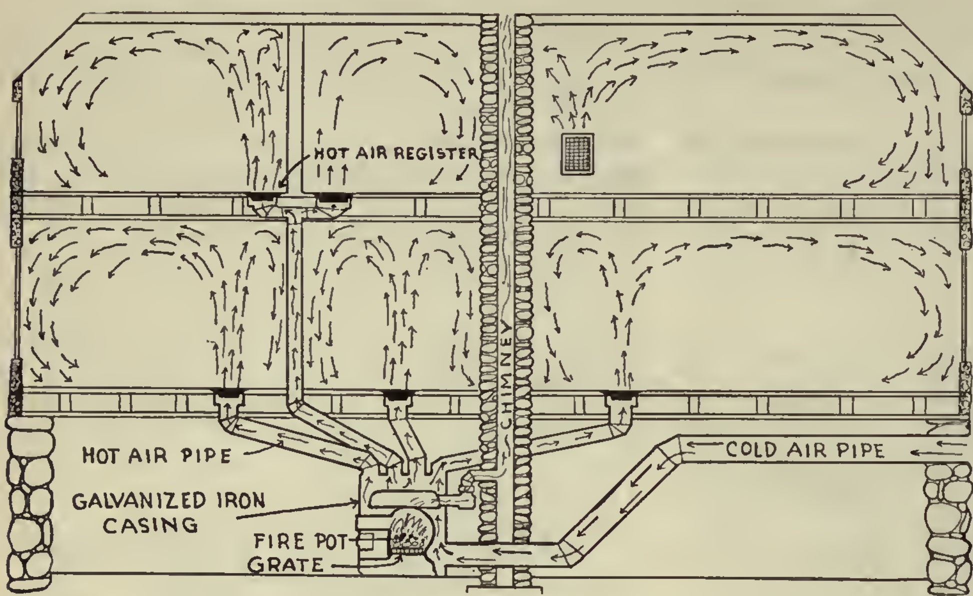


FIG. 210
WARM-AIR
HEATING SYSTEM

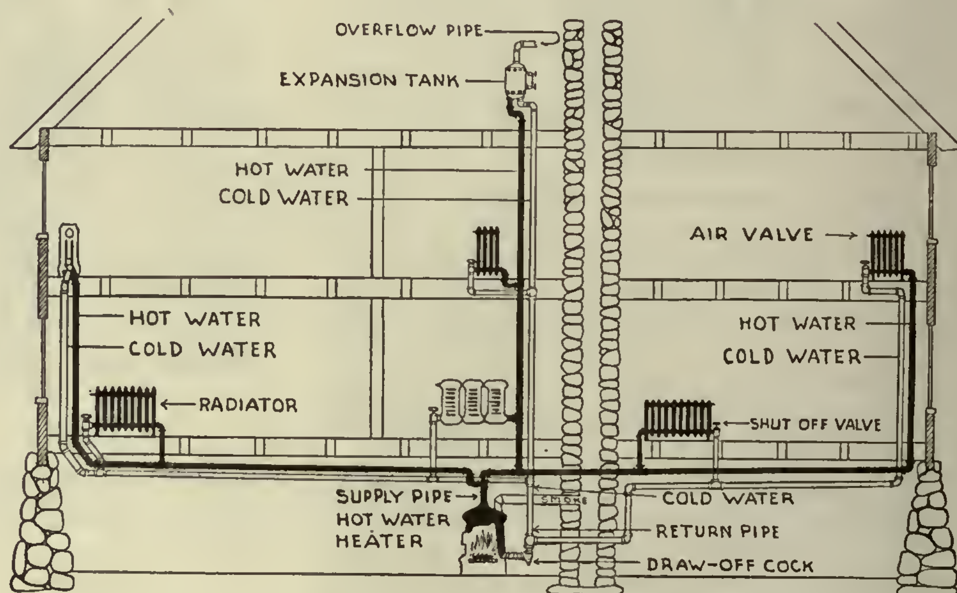


FIG. 211
HOT-WATER
HEATING SYSTEM

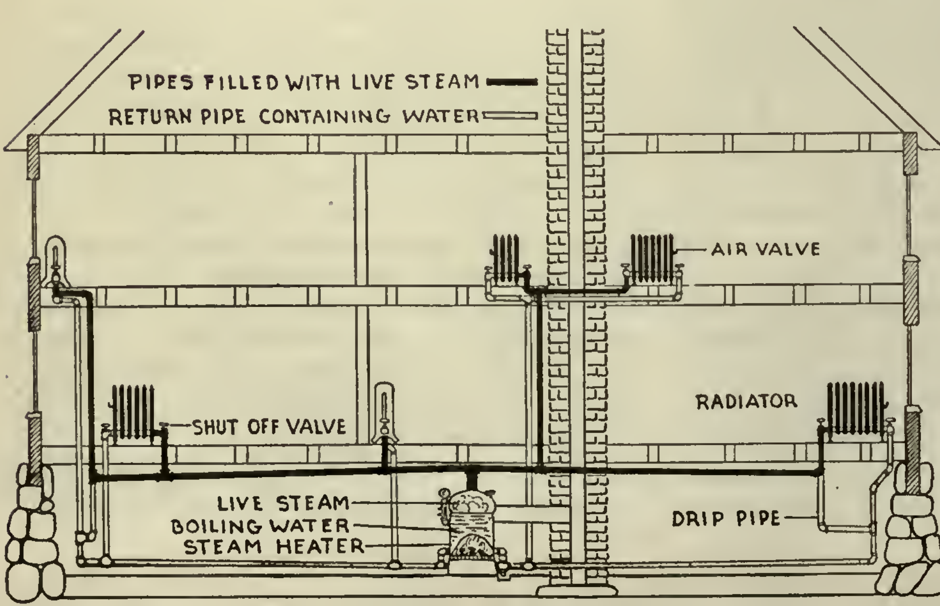
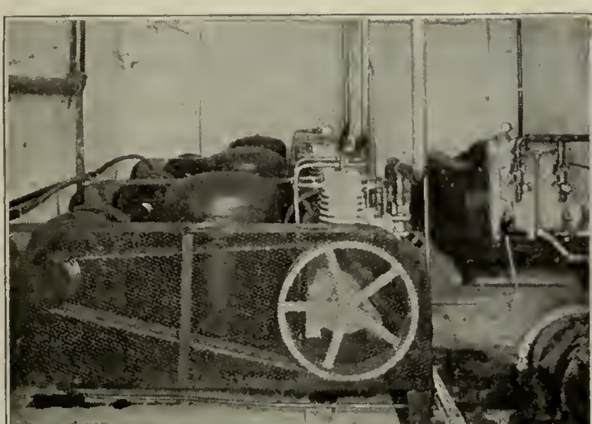


FIG. 212
STEAM HEATING
SYSTEM

high cost of electricity in most communities prohibits their general use.

Exercise. *From your study of home heating reach conclusions bearing on the following questions. The answers to these should be recorded. Which of the three commonly used methods of house heating is best adapted for providing the proper amount of moisture or humidity in the air? Can you suggest a way in which air could be humidified for each of the types of heating system? Much of the heat in the home is lost through the walls and ceilings of the rooms to the outside. Modern methods employ insulation to reduce this loss. Of the materials listed in the table on page 131, which ones do you think might be used for house insulation? Can you suggest other materials that are used for this purpose?*

What is air conditioning? Today we are hearing so much about air conditioning that it is important for everyone to learn the facts concerning it in order that we may know how to judge intelligently about its problems. Air conditioning means the controlling of the factors which make for the greatest health and comfort in the air of our homes and public buildings. These factors are the purity, relative humidity, and temperature of the air.

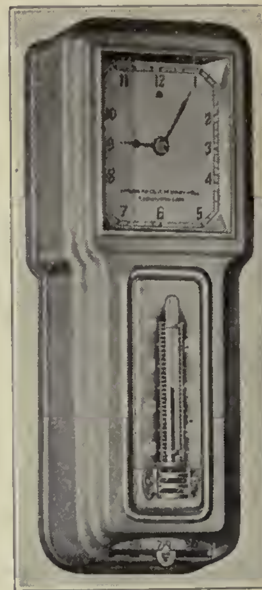


Courtesy General Electric Company

FIG. 213. CONDENSING UNITS FOR AIR CONDITIONING IN A THEATER

In the past the greatest concern about air conditioning has been to heat the air in our homes and public buildings in winter. This we now know is not sufficient. Air temperatures may be controlled in summer. Clean air, properly humidified, may be provided at all times of the year. In recent years many industrial plants and public buildings have been air-conditioned, and now many companies offer air-conditioning equipment for homes.

In the conditioning of air for a large building such as a theater or industrial plant, the air is drawn in from the outside by large fans. It is sometimes washed through a spray of water to remove dust and other undesirable material. After cleaning, the air is either heated or cooled, provided with the proper amount of moisture, and blown into air ducts which carry it to various parts of the building.



Minneapolis-Honeywell

FIG. 214. THERMOSTAT

In summer the air is cooled by passing it over refrigeration coils. You will recall from your study of Topic 1, Unit II, how temperature may be lowered in a refrigeration system by allowing a compressed gas such as ammonia to evaporate. Such a refrigeration plant is usually used in theaters, industrial plants, and office buildings to cool the air in summer. Figure 213 shows the condensing units of the air-conditioning equipment used in a large theater. In the winter the air is heated by blowing it over heating coils. In both summer and winter the air is provided with moisture to give the proper relative humidity.

Today many of our homes are equipped with heating plants which are controlled automatically. The drafts of coke or coal-burning furnaces are opened when the temperature drops and closed when it rises. Oil and gas burning furnaces are also controlled automatically. The device which makes this possible is known as a thermostat (Fig. 214). The thermostat contains a coil which is very sensitive to changes of temperature. It is made of two pieces of metal and is sometimes known as a compound bar. One of the metals expands and contracts with a given temperature change much more rapidly than the other. This tends to make the coil straighten. The thermostat is so constructed that, when the temperature of a room begins to drop and the bar to contract, an electric contact which turns on an electric motor is made. This motor may either turn on the drafts of a coal or coke furnace or start the burner of an oil or gas furnace. When the temperature begins to rise, the compound bar expands, and after the temperature has reached a certain point, the bar makes an electrical contact on the other side and the motor is shut off. Figures 215 and 216 show an oil burner and a gas burner, both of which are controlled by thermostats.

Air conditioning in homes at the present time does not seem to be entirely practicable because there are

so many air leaks in our houses. In the home of the future, no doubt, air conditioning will be commonplace because houses will be constructed for it. That is, all outside openings will have to be almost airtight. Windows will be used to admit light only and not for ventilation at all. Air will be taken in and either

Courtesy Shell Petroleum Corporation

FIG. 215. FURNACE WITH OIL BURNER

heated or cooled, depending upon the season, filtered to remove dust, and then provided with sufficient moisture to give the humidity needed for health and comfort.

Air-conditioning devices on the market today no doubt are of high quality, but the whole problem is one to be viewed critically in the light of present-day home construction.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 10
Clement, Collister, and Thurston, *Our Surroundings,* Chaps. 7, 8
Hunter and Whitman, *My Own Science Problems,* Unit 5
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 20
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 10

Courtesy St. Louis County Gas Company

FIG. 216. GAS BURNER IN FURNACE

Powers, Neuner, and Bruner, *The World around Us,* Chap. 19
Skilling, *Tours through the World of Science,* Tour 14
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 14
Watkins and Bedell, *General Science for Today,* Chap. 21
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 1 (part)
Wood and Carpenter, *Our Environment: How We Use and Control It,* Unit 2, Topic 7

Special references

Forman, *Stories of Useful Inventions*
Knox, *All About Engineering*
Earle, *Home Life in Colonial Days*
Farmers' Bulletin No. 1230, *Chimneys and Fire Places*

Courtesy General Electric Company

FIG. 217. AIR-CONDITIONING UNIT IN THE HOME

Bureau of Mines Technical Papers
No. 97, *Saving Fuel in Heating a House*
No. 208, *How to Improve the Hot-Air Furnace*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of how heat is transferred from one place to another by conduction, convection, and radiation.
2. Skill in taking care of the heating devices in your own home economically.
3. Knowledge of the construction and operation of hot-air furnaces, hot-water heating plants, steam heating plants.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. In what three ways is heat distributed from one place to another?
2. The heat from a hot-air furnace travels mainly by ____.
3. The heat from the sun reaches the earth by ____.
4. When heat travels from molecule to molecule in a substance, the process is called ____.
5. The transference of heat by currents is called ____.
6. The transference of heat from one place to another without the aid of ____ through a medium called ____ is called radiation.
7. The ____ system of heating is the cheapest to install.
8. Which of these two systems is cleaner, hot-air or hot-water?
9. Which system provides the better ventilation in a house, hot-water or hot-air?
10. In what ways do steam and hot-water heating systems differ?
11. In general, ____ are the best conductors of heat energy.
12. Suggest a reason for not making radiators used in steam or hot-water heating systems from polished metal.
13. Hot-water and steam radiators are frequently painted with aluminum paint. Criticize this practice from the point of view of heating efficiency.
14. The ____ bar of a thermostat is made of ____ metals. One of these ____ more rapidly than the other, thus making the bar tend to ____.
15. What are the three factors to be considered in air conditioning?
16. Explain what relative humidity is and how it is determined.

TOPIC 4. HOW FIRE IS CONTROLLED AND PREVENTED

SUGGESTED PROBLEMS AND QUESTIONS

1. What is meant by kindling temperature?
2. How did our forefathers light their fires?
3. What are the scientific principles underlying the match?
4. How may fires be controlled?
5. How is a fire extinguisher constructed and operated?

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems to see if they involve questions which you have wondered about or are interested in.

2. Much of the material in this topic is largely informational and will require considerable reading from special references.

3. Some of the material for problem 4 you should be able to gather from your own experiences and observations.

4. In connection with problem 5 find out what materials are necessary to make a fire extinguisher. The materials are inexpensive and your teacher will help you find them.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 95. Do different substances have different kindling temperatures?

Obtain a small piece of each of the following substances: wood, paper, sulphur, and phosphorus. *(Be very careful in handling phosphorus as it burns readily. Handle it only with forceps.)* Set up apparatus as shown in Figure 218. Light the Bunsen burner and observe carefully what happens. Which substance started to burn first? List the substances in the order in which they started to burn. How do you explain this?

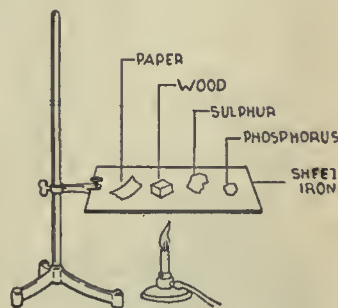


FIG. 218

Activity 96. What are the common causes of fire?

Uncontrolled fire causes losses of millions of dollars to our nation each year. It is important that every citizen of our country know what the causes of fire are and how to prevent them. Investigate this problem and make a tabulation showing causes of fire and methods of preventing fires from the causes named.

Experiment 97. How is a fire extinguisher made and operated?

A small model fire extinguisher is easy to make. Find a wide-mouthed bottle of about a quart capacity. Dissolve two tablespoonfuls of baking soda (bicarbonate of soda) in a pint of water and pour into the quart jar. Fill a small test tube with dilute sulphuric acid and place it inside the quart bottle as shown in Figure 219. Place the cork with a piece of glass tubing in the bottle. The extinguisher is now ready to use. Invert the bottle

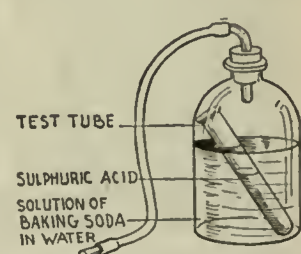


FIG. 219

[1] See workbook, p. 48.

and point the glass tubing toward the fire. The gas generated is carbon dioxide. It is heavier than air, does not burn, and does not aid burning.

What makes the liquid come out of the bottle? What causes the fire to go out?

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

We have already learned that fuels contain carbon and hydrogen which unite with oxygen from the air during combustion. Everyone knows from common observation, however, that a piece of paper or a stick of wood will not start burning of itself. Why is this?

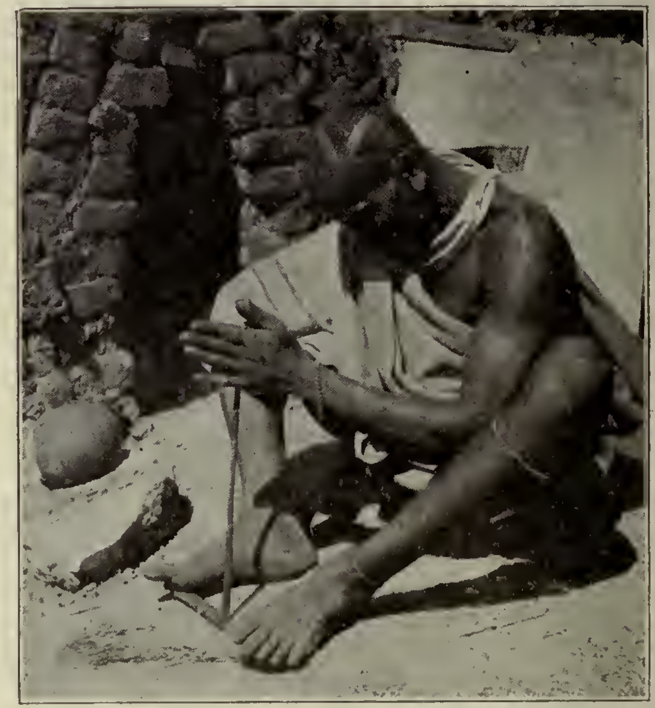
What is meant by kindling temperature? In addition to oxygen, the proper temperature is needed for burning. *The temperature at which a substance starts burning is called its kindling temperature.* Different substances require different degrees of intensity of heat to take fire, and some substances have much lower kindling temperatures than others. If you have performed the experiment suggested at the beginning of this topic, you should have noticed that phosphorus started burning much more quickly than paper or wood. This was because its kindling temperature is much lower than that of the other substances.

When we want to burn coal we usually put paper in the stove or furnace first, then "kindling" wood on top of the paper. The heat from a match furnishes sufficient heat to ignite the paper, and the heat from the burning paper raises wood to its kindling temperature. After the wood is burning well we put coal on top, as sufficient heat is developed by burning wood to raise coal to its kindling temperature.

How did our forefathers light their fires? How or when man first learned to start a fire is not known. It is known that before historic times fires were started by rubbing two pieces of wood together until enough heat was produced to make a spark which was used to kindle a fire (Fig. 220). Another primitive method consisted of striking flint (a type of rock) upon steel to produce a spark.

Our forefathers used the flint-and-steel method to start their fires. The sparks produced were caught in some tinder, a substance such as dried bark or moss which caught fire readily. It was a common practice before the invention of matches to save hot coals each evening to start the fire the next day rather than use flint and steel every time a fire was needed. If the coals went out before morning, as they occasionally did, it was the custom to borrow some from a neighbor. The hot coals were carried in little covered iron containers made especially for that purpose.

What are the scientific principles underlying the match? During the seventeenth century it was discovered that sulphur could be used in making a fire because it begins to burn at a much lower temperature than wood and because the heat furnished is sufficient to ignite wood. The "parlor match" was not invented, however, until about 1823. The head of the common "strike-anywhere" match usually consists of a mixture of phosphorus, potassium chlorate (a substance containing oxygen), powdered glass or sand, and glue. Since phosphorus has a very low kindling temperature, rubbing the match against a rough surface produces enough heat to ignite the phosphorus, which in turn lights the match stick.



Keystone View Company

FIG. 220. MAKING FIRE BY FRICTION

The head of a safety match is made of a substance that burns readily, and the phosphorus and powdered glass or sand are placed on the rubbing surface of the box. The head of the match will not burn unless rubbed over the phosphorus on the box.

How may fire be controlled? Fire is of inestimable value to man, but when it gets out of control it causes tremendous damage and loss. Records kept by fire insurance companies and government bureaus show that the property losses in this country from fire alone amount to over a half billion dollars a year. Also thousands of people lose their lives each year from fire. Most fires are caused by thoughtlessness and carelessness in the care of things about homes and buildings, such as the heating plant and chimney, rubbish, matches, electrical devices and wiring, and the use of kerosene and gasoline.

The improper care of heating devices frequently results in disastrous fires. Hot stove and heater pipes

should always be covered with heavy insulating material such as asbestos. Stoves and furnaces should never be placed near woodwork. Kerosene or gasoline should not be used to kindle a fire. The vapor of these substances forms explosive mixtures with air, and many people have been fatally burned from resulting explosions. Ashes should always be kept in metal containers. The flues and chimneys of furnaces should be kept clean and in good working order at all times.

Common matches are a fire hazard. They should be kept away from small children and protected from rats and mice. Only matches of the best quality should be used. The most desirable match is the safety match, which ignites only when rubbed upon the side of the box.

Many fires are caused through the use of electrical equipment. Read carefully the following statements which give the precautions necessary in the use of electricity and electrical equipment.

> Never wire buildings without proper insulation.
>
> Always be sure you are using the proper fuses.
>
> Never have too many electrical devices operating at the same time.
>
> Never leave an electrical heating device while the current is turned on.

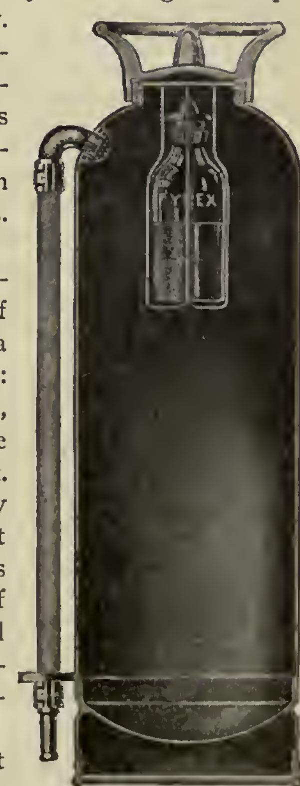
FIG. 221. HOW TO ELIMINATE FIRE HAZARDS

> See that electrical wires are always covered with insulation.
>
> Never use too small wires for a heavy current.

The use of illuminating devices such as candles, kerosene and gasoline lamps, and gas flames increases the dangers of fire in the home. These devices should always be used with the utmost care.

> Never have lamps near curtains or drapery.
>
> Never use lamp shades made of materials that burn readily unless the flame is protected by an insulating substance.
>
> Never fill a kerosene or a gasoline lamp while it is lit.
>
> Never have lamps where they can be easily upset.

Sometimes fires occur as a result of *spontaneous combustion.* Have you ever heard of a stack of uncured hay catching fire of itself? When substances combine with oxygen of the air, heat is formed. Ordinarily when slow oxidation takes place the heat is immediately given off. Some substances unite with oxygen and the heat is retained. As a result the temperature continues to rise until the kindling temperature is reached, when the substances burst into a flame and burn rapidly. This is called spontaneous combustion. It is believed that a considerable number of farm buildings are burned each year through the spontaneous combustion of hay. Hay should always be thoroughly cured and dry before it is put into the mows or stacks. Oily rags and cotton waste should be kept in covered metal containers. Why?



American-LaFrance-Foamite

FIG. 222. COMMERCIAL FIRE EXTINGUISHER

How are fires extinguished? From our study of burning we learned that a fire requires three things: a combustible substance, oxygen, and a temperature above the kindling point. If a fire is deprived of any one of these three things, it will go out. In fighting fires we generally try to cut off the oxygen supply or cool the burning substance below its kindling temperature or both.

Water is one of the best and most widely used fire extinguishers. The properties it possesses make it very useful for this purpose.

It will not burn, it has greater cooling power than other substances, it changes to steam and absorbs large quantities of heat, and being a liquid it can be thrown long distances in steady streams upon a fire.

How is a fire extinguisher constructed and operated? Several types of commercial fire extinguishers are in general use. Figure 222 shows a carbon dioxide type. Notice the small bottle at the top. It contains an acid solution. In use this extinguisher is grasped by the handle and turned upside down. The acid flows out of the bottle and combines with the soda solution. Large quantities of carbon dioxide are generated, creating a pressure inside the can that forces carbon dioxide and water out of the hose. The fire is extinguished by the cooling effect of the water and by the water vapor and carbon dioxide cutting off the oxygen supply.

Another form of fire extinguisher contains the chemical, carbon tetrachloride. Carbon tetrachloride is a non-combustible substance that vaporizes at a low temperature The vapor is about five times heavier than air. When thrown on a fire the vapor forms quickly and settles over it, cutting off the oxygen supply. This type of extinguisher is coming into greater use where a small extinguisher is practicable as in automobiles and houses. It is especially useful around electrical equipment because the vapor is not a conductor of electricity. It is also particularly valuable for extinguishing small oil and gasoline fires where water would spread the fire.

Homes and schools should be provided with small fire extinguishers and every person should be taught how to use them. If a fire breaks out in your home and a fire extinguisher is not available, throw water, sand, or dirt on the flames to cut off the oxygen supply. If some person's clothing catches on fire wrap a blanket or a rug around him. Why? Instruct him not to run as running makes the fire burn better.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 11

Clement, Collister, and Thurston, *Our Surroundings*, Chaps. 7, 8

Hunter and Whitman, *My Own Science Problems*, Unit 5; *Science in Our World of Progress*, Unit 13 (part)

Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 4 (part)

Pieper and Beauchamp, *Everyday Problems in Science*, Unit 9

Skilling, *Tours through the World of Science*, Tour 14

Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 2

Watkins and Bedell, *General Science for Today*, Chap. 19

Wood and Carpenter, *Our Environment: Its Relation to Us*, Chaps. 10, 12; *Our Environment: How We Use and Control It*, Unit 2, Topic 7

Special references

Marshall, *The Story of Human Progress*

Book of Knowledge

Williams, *How It Is Made*

Forman, *Stories of Useful Inventions*

Moffett, *Careers of Danger and Daring*

Jewett, *Town and City*

Whitman, "Fire Hazards and Safeguards," *General Science Quarterly*, March, 1920

National Board of Fire Underwriters, *Safeguarding the Home Against Fire*

Hill, *Fighting a Fire*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. What the primitive methods of making fire were.
2. The science of the match.
3. Skill in starting a fire without the aid of a match.
4. Skill in extinguishing fires.
5. What common fire hazards are.
6. The construction and operation of a fire extinguisher.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. What people obtained fire by rubbing together two sticks of dried wood?
2. What people obtained fire by striking together flint and steel?
3. Write a paragraph on "The Making of a Match."
4. List here all the fire hazards you can think of.
5. If your clothing caught on fire, how would you extinguish the blaze?
6. Two chemicals used in a fire extinguisher are ____.
7. Write a paragraph explaining how you would build a fire in the woods.
8. If a fire suddenly broke out in your home, what would you do?

TOPIC 5. PROTECTING OUR BODIES WITH CLOTHING

SUGGESTED PROBLEMS AND QUESTIONS

1. **How is the temperature of our bodies regulated?**
2. **What is the scientific reason for wearing different kinds of clothing in different seasons of the year?**
3. **What are the sources of the different types of fibers used for making clothing? How can the principal fibers be identified?**
4. **How is clothing kept clean?**
5. **How may stains be removed from clothing?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully read the problems before beginning your study and experimentation.

2. In connection with problem 3 you should experiment with the various tests used to identify the more common fibers.

3. In connection with problem 5 find out how to remove the following stains: blood, ink, grass, and grease.

4. The following words in this topic may be new to you. Use them as often as possible to make them a part of your vocabulary.

microscope—an instrument that makes small objects appear larger to the human eye.
cocoon—the case in which the silkworm lives while developing into a silk moth.
bleach—to make white.
javelle water—a bleaching agent made by dissolving chloride of lime and baking soda in water.

EXPERIMENTS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Activity 98. What is the source of each of the different fibers used in making clothing?

Make a table of two columns; head the first column "Fiber" and the second column "Source." In the first column list the fibers wool, natural silk, artificial silk, flax, fur, and linen. In the second column write the sources of these fibers.

Experiment 99. How may the principal fibers be identified?

Obtain pieces of fabrics made from wool, cotton, linen, natural silk, and artificial silk. Examine threads of each under a magnifying glass or a miscroscope. Make drawings of each type of fiber as it appears to you.

Fray the edges of a sample of each piece of fabric. Hold the frayed edges of each sample in a match flame. Make notes on the different rates of burning, the different odors produced during burning, and the fibers that become gummy as they burn.

Experiment 100. How can real silk be distinguished from artificial silk?

Obtain a piece of fabric made of natural silk and one made of rayon (artificial silk). Test the strength of each piece. Wet each piece with water. Test their strength again. Which is weakened by the water?

Boil samples of each fabric in a lye solution. Which of the two fabrics is dissolved?

Pull out threads from each piece of cloth. Burn them. Which piece burns rapidly without much odor? Which burning fibers produce an odor of burning hair?

Experiment 101. How can mixed goods be identified?

Obtain samples of mixed wool-cotton and silk-cotton goods. Make a lye solution by dissolving three heaping tablespoonfuls of lye in a quart of water. Place samples of the two types of goods in different dishes and cover each with lye solution. Boil each for several minutes. The wool and silk fibers will be dissolved by the lye solution, leaving the cotton fibers.

Experiment 102. How does laundering affect different fibers?

Secure samples of cloth made of cotton, linen, silk, and wool. Cut the samples into pieces of the same size. Make two duplicate pieces of each type. Boil one set of samples in water and lay them out to dry. When they are dry compare with the original samples. Did any of the fabrics shrink? Were any of the fabrics weakened by the boiling water?

Wash samples of the fabrics in hot water with soap. Rinse and dry. Were the fabrics affected in any way?

Make a strong washing soda solution by dissolving as much washing soda in the water as it will hold. Boil samples of the different fabrics in the washing soda for about ten minutes. Wash and dry the samples. Are any of the fabrics weakened by this process?

Experiment 103. How are stains removed from fabrics?

The proper care of clothing and household textiles requires a knowledge of how stains are removed. Most stains can be removed easily at home, if reliable methods are known and a few simple precautions taken. Some common causes of stains are blood, grease, grass, fruit, coffee, writing ink, iron rust, ice cream, tar, axle grease, and shoe polish. List these causes of stains in a column; consult references and write opposite each cause of stain the method by which the stain may be removed. Farmers' Bulletin No. 1474, U. S. Department of Agriculture, *Stain Removal from Fabrics by Home Methods,* is an excellent reference. Write to the U. S. Department of Agriculture for this bulletin. Try out some of the methods.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How is the temperature of our bodies regulated? We learned in a previous unit of study that the temperature of our bodies remains at about 98.6° F. the

[1] See workbook, p. 49.

year round, regardless of the temperature of our surroundings. How does the body maintain this constant temperature? The temperature of the body is regulated largely by means of the activity of the sweat glands. Beneath the surface of the body are tiny blood vessels, many of them surrounding the sweat glands. As the temperature of the air around the body increases or when muscular activity is increased through exercise or work, the blood is heated. This increases circulation and thus causes the blood vessels to expand; this change in turn stimulates the sweat glands to secrete more perspiration. The evaporation of more perspiration cools the skin, and the cooling of the skin in turn cools the blood. In this way the body maintains an even temperature.

What is the scientific reason for wearing different kinds of clothing in different seasons of the year? Clothing does not furnish heat to the body. Heat is obtained in the body by oxidation of the food that we eat. Clothing simply helps the body to retain or lose heat.

The value of clothing is generally considered from two standpoints: its ability to conduct heat from the body and its power of absorbing moisture. In winter our problem is to find clothing that is a poor conductor of heat but that will absorb large quantities of moisture. Woolen clothing is widely used for winter wear because it possesses both of these qualities. Since air is a very poor conductor of heat, clothing for winter wear is generally woven so as to contain much air. Do you know why a cotton blanket seems warmer than a cotton sheet? In summer linen and cotton fabrics are worn next to the skin because their fibers are better conductors of heat and also because they give up moisture to the air quickly, thereby giving a cooling effect to the skin.

International News Photos, Inc.

FIG. 223. COTTON BOLL

What are the sources of the different types of fibers used for making clothing? The fibers from which clothing is made may be obtained from plants or animals, or they may be produced artificially from inorganic matter. The principal fibers used in this country are cotton, wool, linen, silk, and rayon (artificial silk).

Cotton is obtained from the cotton plant. The fruit or boll (see Fig. 223) of the cotton plant contains seeds, each of which has fine, white, twisted hairs clinging to it. These fibers enable the wind to distribute the seeds over a wide territory in much the same way as dandelion and milkweed seeds are distributed. These fibers are the raw cotton. The cotton is picked and the seeds are removed by a machine called the cotton gin. Then the fibers are pressed into bales and shipped to cotton mills where they are woven into cloth. More than eight billion square yards of cotton goods are manufactured and used in this country annually.

International News Photos, Inc.

FIG. 224. PICKING COTTON

Cotton fibers are treated and woven in a large number of ways, producing many varieties of cotton fabrics. Each variety is sold under a different name[1] such as gingham, calico, flannel, muslin, denim, percale, organdie.

Wool is obtained from sheep. Sheep raising is carried on extensively in this country as well as in South America and Australia. The wool is clipped from the animals generally once a year, and then shipped to mills. Here it is sorted, cleaned, and dried. Then it is carded or combed and spun into yarn from which woolen cloth is made.

If you examine wool under a microscope you will see that it is composed of many cells overlapping each other, which give it a rough, scaly appearance. This characteristic of wool makes it finer and softer than other fibers as the scales of the fibers mat together.

Linen is a fiber of vegetable origin. Linen fibers are obtained from the inner bark of the flax plant. This plant is cultivated extensively in Ireland and to a lesser extent in other European countries. Irish linen is generally considered to be the best.

[1] *Farmers' Bulletin No. 1449*, U. S. Department of Agriculture, March, 1926, lists and describes about a hundred varieties of standard cotton fabrics. The bulletin can be obtained from the U. S. Department of Agriculture for five cents.

Linen clothing is most satisfactory for wear in warm weather or in tropical climates. This is due to three factors: (1) linen is the best conductor of heat of all textile fibers, (2) linen absorbs moisture from the body rapidly and also permits moisture to evaporate rapidly from it, and (3) air is able to pass through linen fibers readily.

Raw silk is a textile fiber of animal origin obtained as a product from the silkworm. The silkworm is not a worm, however, but one of the stages in the life history of a moth. Moths are insects, and like butterflies they pass through four stages (egg, larva or caterpillar, pupa, and adult) before their lives are completed.

Paul's Photos

FIG. 225. SHEARING SHEEP IN AUSTRALIA

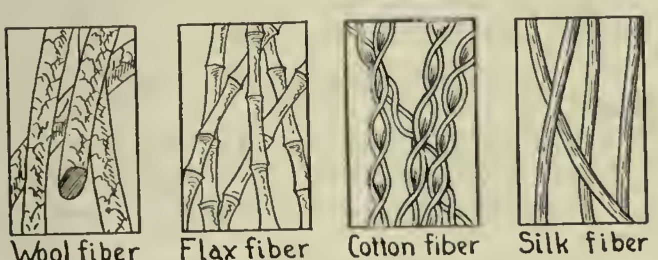
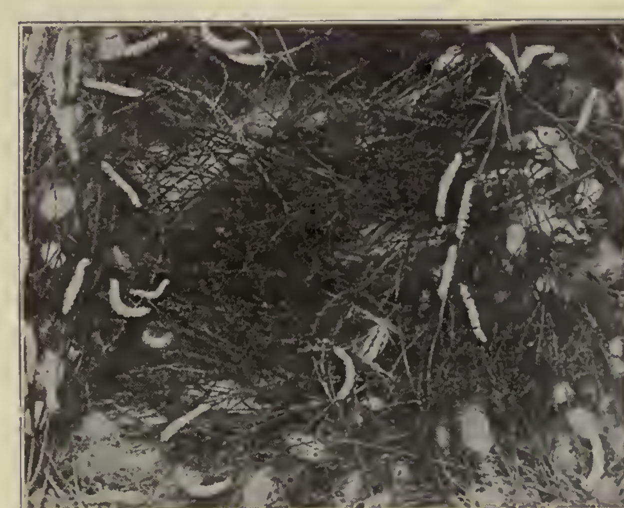


FIG. 226. TYPES OF FIBERS

The raising of silkworms has been carried on in China since 3000 B.C. Silkworm eggs that develop into young caterpillars (the larva stage) are collected. These caterpillars feed on mulberry leaves, grow rapidly, and then spin cocoons around their bodies. The cocoon acts as a protective covering during the change from the caterpillar stage to the adult stage. This is called the pupa stage. The pupae are killed by placing the cocoons in hot water. Then the cocoons are dried and the silk fibers reeled from them. This raw silk is sent to factories where it is treated with various chemicals and woven by machinery into different styles of fabrics which are sold to us as silk, georgette, satin, velvet, etc.

Nearly three thousand silkworm cocoons are required to produce a pound of raw silk. Since most of the labor in the production of the reeled silk is done by hand, silkworm raising is confined largely to nations like India, Japan, and China, where labor is cheap.

Marked progress has been made in recent years in man's attempt to imitate nature's processes. Artificial silk or rayon is made from cellulose obtained principally from cotton or wood. Cellulose is dissolved in a chemical substance and then forced through small openings into some solution in which it is insoluble. Fine filaments, shaped like a tube and regular in outline, are formed from this treatment.



International News Photos, Inc.

FIG. 227. SILKWORMS AT WORK

In some respects rayon is more desirable than natural silk. It possesses a greater luster than natural silk and takes direct cotton dyes readily, with the production of rich shades of color. It is also only about one-third as expensive as real silk. Its chief disadvantage is that it is not as strong as real silk. Rayon fibers show a decided weakness when wet; therefore great care must be exercised when washing them, otherwise the fibers will be broken. Methods of improving the strength of rayon have been found which have resulted in considerable improvement in this respect.

How is clothing kept clean? It is important, for at least two reasons, that we keep our clothing clean. First, clean, neat clothing gives us a more attractive appearance. All of us are judged to some extent by our personal appearance. Second, it is more healthful

to wear clean clothing. Soiled clothing may harbor germs which increase the danger of infection if the skin is cut or bruised.

Water is a universal cleansing agent. With the addition of soap to water nearly all forms of dirt with the exception of stains may be removed from clothing. Have you ever wondered how soap cleanses? When we wash our hands or clothing with soapy water a soap film forms around little drops of grease, oil, or dirt and forms a lather. This lather is easily removed from our hands or clothing by rinsing with water which carries the dirt particles along with it.

Dry cleaning and pressing are used on clothing when the use of soap and water would injure the fabrics or cause them to shrink too much. In the dry cleaning process the clothes are usually washed in gasoline or benzine, which removes grease and oil by dissolving them. Possibly you have detected an odor of one of these liquids on clothing that has just come from a dry cleaning establishment. Dry cleaning can be carried on in the home, but carbon tetrachloride should be employed in place of gasoline, benzine, or naphtha. The vapors of gasoline, benzine, and naphtha form explosive mixtures with air, and they are also highly inflammable. Carbon tetrachloride is not inflammable, nor does it support combustion. Thus it is much safer to use.

How may stains be removed from clothing? The removal of stains is an important problem in connection with the cleaning and care of clothing. The following general rules for stain removal are suggested in *Thrift Leaflet No. 6,* United States Department of Agriculture and Treasury Department.

Treat promptly. A fresh stain comes out more easily than an old one.

Find out what made the stain. Some stains are set by treatment that would remove others.

Consider the material. White and colored goods, cotton, linen, silk, and wool should not always be treated in the same way.

Try simple methods. They often do the work and are not likely to harm the material.

Work carefully. Experiment on a sample. Rub gently. Haste makes waste in taking out spots.

Nearly all the common substances used to remove stains may be classified as follows:

Absorbents—materials like blotting paper and chalk that remove stains by absorbing them.

Solvents—materials like water and carbon tetrachloride that remove stains from fabrics by dissolving them.

Chemicals which react with the stain with the formation of substances that are colorless or soluble, or that are both colorless and soluble.

The table on this page gives methods of removing common spots and stains. Try to place each method in one of the three classes mentioned.

Methods of Removing Common Stains

Stain	How to remove it
Acids	Apply ammonia water or baking soda.
Alkalis	Apply lemon juice, vinegar, or 10% solution of acetic acid.
Blood	Soak in cold water and sponge with hydrogen peroxide.
Butter	Use carbon tetrachloride.
Chewing gum	Treat alternately with carbon tetrachloride and water.
Coffee	Wash thoroughly and dry materials in sunlight.
Fruit	Apply boiling water and oxalic acid.
Grass and leaves	Sponge with alcohol; then wash.
Grease	Use carbon tetrachloride.
Ink	See *Farmers' Bulletin No. 1474,* U. S. Department of Agriculture.
Lubricating oil	Use carbon tetrachloride.
Iron rust	Sprinkle stain with salt, moisten with lemon juice, and place in the sun.
Milk and cream	Sponge first with carbon tetrachloride and then with water.
Oil paints, varnishes, and enamels	Sponge with pure turpentine.
Tar, road oil, and axle grease	Immerse fabrics in carbon tetrachloride and rub. Follow by thorough washing in soap and water.
Tea and coffee	Keep stain moist with lemon juice and expose to sunlight for a day or two.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 12
Hunter and Whitman, *My Own Science Problems,* Unit 5
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 8
Powers, Neuner, and Bruner, *This Changing World,* Chap. 14 (part)
Skilling, *Tours through the World of Science,* Tour 14
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 15
Watkins and Bedell, *General Science for Today,* pp. 462-466
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 4 (part)
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It,* Unit 2, Topic 9; *Our Environment: How We Use and Control It,* Unit 7, Topic 22

Special references

Bassett, *The Story of Silk*
Manchester, *The Story of Silk*
Carpenter, *How the World Is Clothed*
Bassett, *The Story of Wool*
Brooks, *The Story of Cotton*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The sources of the various fibers used in clothing.
2. The types of fibers best for cold and hot weather and scientific reasons for their suitability.
3. How to identify wool, cotton, silk, or mixed goods.
4. How to remove stains from clothing.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The usual temperature of the human body is ____ degrees Fahrenheit.
2. The fiber that is the poorest conductor of heat is ____.
3. The fiber that conducts heat best is ____.
4. The coolest clothing to wear in summer is made of ____.
5. Air is a ____ conductor of heat.
6. Black clothes are ____ than light colored clothing.
7. ____ is removed from the human body by evaporation of perspiration.
8. Linen is made from ____.
9. Silk is a ____ conductor of heat.
10. A grease spot can be removed from clothing by ____.
11. Soap is made from ____ and ____.
12. Artificial silk is made from ____.
13. How would you remove an ink stain from clothing?
14. How would you remove a blood stain from clothing?
15. How would you test for cotton fiber in clothing?
16. How would you test for wool in clothing?

SUPPLEMENTARY MATERIALS

Reading suggestions

Kenlon, *Fires and Firefighters* (Doubleday)
Weeks, *The Avoidance of Fires* (Heath)
Crump, *The Boys' Book of Firemen* (Dodd)
Gibson, *The Romance of Modern Manufacture* (Lippincott)
Philip, *Achievements of Chemical Science* (Macmillan)
White, *Fuels of the Household* (Whitcomb & Barrows)
Tappan, *Diggers in the Earth* (Houghton)
Williams, *The Romance of Mining* (Lippincott)
Carpenter, *How the World Is Housed* (American Book)
Elliot, *The Romance of Savage Life* (Lippincott)
Tappan, *Makers of Many Things* (Houghton)
Earle, *Home Life in Colonial Days* (Macmillan)
Reisbeck, *Air Conditioning* (Goodheart-Willcox)
Broadhurst and Lerrigo, *Health Horizons* (Silver)
Worthington and Matthews, *Our Clothing* (Owen)
Greene, *Coal and the Coal Mines* (Houghton)

Reports which may be prepared

1. How coal is mined
2. Our common fuels and how they are used
3. How matches are made
4. How to fight forest fires
5. Methods of making fires
6. Manufacture of artificial gas
7. Advantages and disadvantages of various fuels and of electricity
8. Life and works of Sir Humphry Davy
9. Early types of thermometers
10. Using oil for heat in the home
11. Using gas for heat in the home
12. Insulating the modern home

Great scientists you should know about

1. Galileo
2. Sir Humphry Davy

Investigations and things to do

1. Make a thermometer for your home.
2. Survey your home for fire hazards and remove them.
3. Visit a local fire station and prepare a report for class.
4. Take care of the heating system in your own home for two weeks and report on the best methods employed.
5. Investigate the regulation of the temperature of the rooms of large buildings by means of thermostats.
6. Examine a gas mantle and make a diagram to show how it is constructed.
7. Make a study of how crude oil is obtained from the earth and how it is refined into many products.
8. Learn how to read a gas meter.
9. Learn how to read an electric meter.
10. Examine a thermos bottle and find out how it keeps hot things hot and cold things cold.
11. Learn how a coal range is constructed and operated.

UNIT VII. USING MACHINES TO HARNESS ENERGY

Man's conquest of nature has been a long and difficult struggle. Ages ago, because of his superior intelligence, man learned that by using a crude weapon made of stone he could more easily subdue his animal enemies and that by means of a stick he could more readily move heavy obstacles. These were probably the first attempts to gain an advantage over natural forces. Later the inclined plane helped him to raise heavy loads to greater heights than would be attainable with the crude lever bar of earlier times. The wedge used with the stone axe aided him in splitting the logs which went into his dugouts and huts. Since then man's progress has been largely a story of continued victories over the resistant forces which surround him.

The more complicated machines such as the wheel and axle, the pulley, and the screw were developed in later ages long after man had learned the use of the simpler ones. These, in combination with the others, form a large part of the foundation of the modern machine age, for most modern mechanisms are made of combinations of six simple machines.

Did you ever stop to consider what an important place machines occupy in our everyday life? At every turn we make use of them to save our strength and time. Machines such as food choppers, can openers, and beaters help in the kitchen, while others work for us in the basement and about the house. In offices, besides writing our letters, they perform tasks that are almost human by adding, subtracting, multiplying, and dividing. The automobile and airplane, each of which is a machine built up of simpler oncs, take us about the country with great speed.

In this unit we want you to learn more about machines and how they work in order that you may use them more intelligently.

How many of these things do you already know?

1. Why are trucks or rollers placed under heavy boxes when they are moved about?
2. Where does energy come from?
3. What is energy?
4. A plank or board is often used as a track to roll heavy objects into a wagon or truck. Explain.
5. Why is one jerked backward in a car that starts suddenly?
6. Why do you hold on to something in a car that is going around a turn?
7. Why does mud fly off the tire of a moving bicycle?
8. Make a list of all the machines used around your home.
9. Find as many advertisements of machines in magazines and newspapers as you can. Paste thesc on a sheet of paper and bring them to class.
10. Why is it easier to unscrew a nut from a bolt with a long-handled wrench than with your fingers?
11. Why are ball and roller bearings used in automobiles and other machines?
12. List as many ways as you can in which friction is made use of in the automobile.
13. How many ways can you list in which energy is changed from one form into another, as from electricity into light?

TOPIC 1. SOME FORCES AND MOTIONS IN DAILY LIFE

SUGGESTED PROBLEMS AND QUESTIONS

1. **Is perpetual motion possible?**
2. **What are the advantages and disadvantages of friction?**
3. **Why do substances have weight?**
4. **Why does one pitch forward in a car that is suddenly stopped, and why are turns on railroads and highways banked?**
5. **How much distance must be allowed for stopping cars traveling at different speeds?**

SUGGESTIONS AND HELPS FOR STUDY

1. In the study of this topic try to see how the principles of science you learn apply in your own daily life. Try to secure any experiences suggested by the problems which you may not have had, such as observing the "bank" on turns of railroads and highways.

2. The following words may be new to you. Carefully study them and after learning their meaning, try to use them frequently so that they may become a part of your vocabulary.

~~*perpetual*~~—never ceasing.

~~*lubrication*~~—the application of liquids or solids to rubbing surfaces to reduce friction; for example, oil is a lubricant.

inertia—the property possessed by all bodics which causes the body to resist being set in motion, or, once in motion, to resist being stopped.

force—a push or pull exerted on a body.

centrifugal force—a force in a rotating body which pulls awav from the center of rotation.

centripetal force—a force in a rotating body which pulls toward the center of rotation.
acceleration—increasing speed of a moving body.
~~*deceleration*~~—decreasing speed of a moving body.
density—the weight of a unit volume of any substance.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 104. What causes friction and how may it be reduced?

Equip a chalk box with four wheels which turn easily and which can be removed. Weigh the box and wheels together and then place a two-pound weight and the wheels

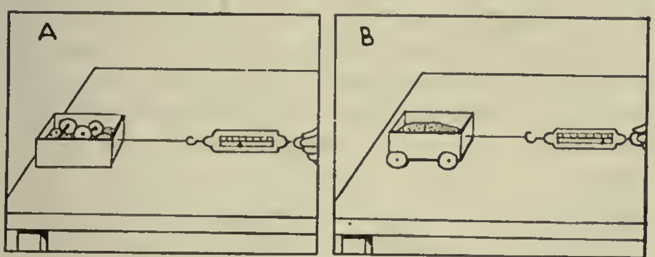


FIG. 228

in the box as a load. Attach a string and spring balance to the box as shown in the illustration and determine the average effort needed to keep the box moving uniformly over the surface of the table top. Keep the balance parallel with the table top. Sprinkle sand on the table top and repeat your measurements. Attach the wheels to the box as shown at *B* in Figure 228. With the table top clean determine the force that is necessary to keep the box and load moving uniformly. Again sprinkle sand on the table top and repeat the measurement.

The effort force is ____ when sand is placed on the table top because sand ____.

The effort force is ____ when wheels are placed under the car.

For each of the four trials, divide the effort force by the total load and express the quotient as a decimal.

Experiment 105. Do equal volumes of different substances have the same weight?

Secure regular solids of such substances as aluminum, brass, wood, iron, lead, glass, and any other that may be available, and carefully determine their volumes in cubic centimeters. Record these in a neat table. If regular solids of these or other substances are not available, devise a method of determining the volume of irregular solids of the same substances by using a graduate. Record these volumes in a neat table. Carefully determine the weight of each solid, in grams, and record it beside the volume as determined above. By calculation find the weight of a unit volume of each of the substances. (Divide the weight by the volume.) Record in the table. Answer the following questions about the experiment. Do equal volumes of all substances have the same weight? Can you suggest a reason why this is true?

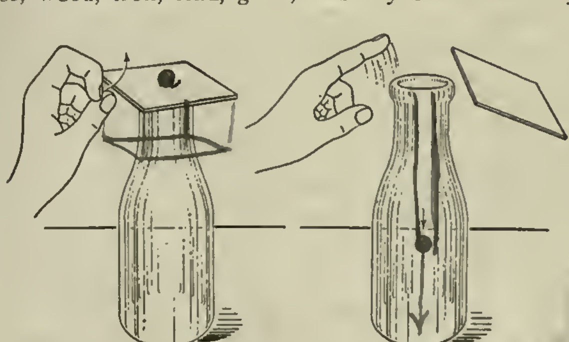


FIG. 229

[1] See workbook, p. 52.

Experiment 106. What is inertia?

Secure a marble, a pint milk bottle, and a piece of thin cardboard about two inches square. Place the cardboard on the top of the milk bottle and the marble on the cardboard. With the thumb and first finger, snap the cardboard

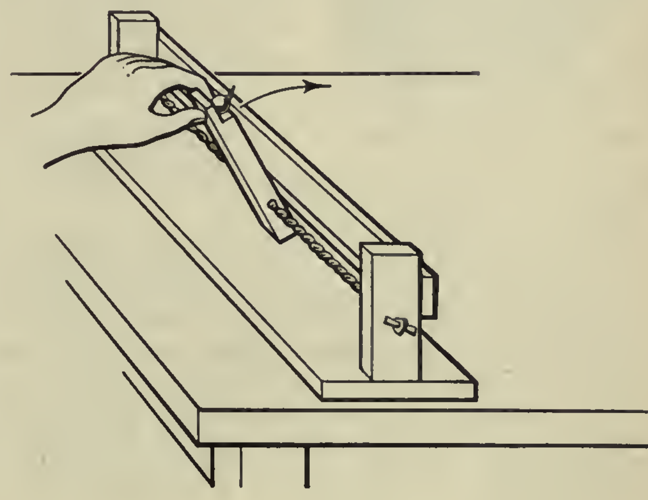


FIG. 230

on one of its corners and observe what happens. Record your results.

Place a smooth sheet of paper on the table and stand a glass of water on it. Give the paper a sudden pull and observe what happens. Record your results.

Cut a notch from a stick of wood as shown in Figure 230. Build a sample frame similar to the one shown and attach the notched stick to it by means of rubber bands or strips of rubber cut from an old automobile tire inner tube. Twist the bands and then place a marble in the notch of the stick as it is drawn back. Let the stick go. What happens when the stick is stopped by the frame. Repeat this several times with different materials as weights and observe the results carefully. Make a record of your findings.

As you try to reach a conclusion in answer to the title question of this experiment, be guided by these questions. Did the marble take up the motion of the card? Was the glass of water pulled off the table when the sheet of paper was set in motion? What happened to the motion of the marble used in the last part of the experiment when the notched stick was suddenly stopped by the frame? What would you have had to do to set the marble in motion?

When a body is at ____ or is in ____ it tends to continue in that condition unless an outside ____ is applied.

Experiment 107. What is centrifugal force?

Place some water in a small pail which has a handle or bail. Swing the pail and water around in a circle with the pail at arm's length. Does the water fall out of the pail? Can you notice a tendency for the water to pull outward against your inward pull on the handle of the pail?

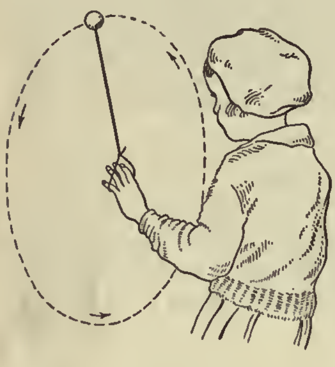


FIG. 231

Tie a small weight on a fairly strong string and whirl this around. Be sure you are away from windows and fellow students when you do this. The best place to try it is outside the school building. Whirl the string and weight around several times and then let it go. Observe the direction it takes by repeating the experiment several times.

Secure a rubber band and cut it to make a single strand of rubber. Tie this to a small weight and whirl the weight around. Compare this result with the one above, where the weight was attached by a string.

Record the results of this experiment carefully. Answer the following questions. How many forces seem to be at work in each of the above cases? Why did the water stay in the pail? Did you observe the forces in the case of the string and weight? What happened when you released the weight? Why did this happen? What was the difference between the string and weight and the rubber band and weight? The force pulling toward the center in these experiments, that is, the force with which you were pulling on the pail and the string, is known as centripetal force. The force pulling away from the center of rotation is known as centrifugal force.

READINGS AND ACTIVITIES WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Is perpetual motion possible? This has been a problem of the ages. Since man began to build machines to aid him in his conquest of natural forces, he has been puzzled with the problems of producing perpetual motion. About the time of the American Revolution the French patent offices were so flooded with models and requests for patents on devices which were supposed to achieve continuous motion that they refused to take more of them. Some of the machines proposed for perpetual motion were interesting and most ingenious. Figure 232 shows one type.

Exercise. *After studying the drawing of a suggested perpetual motion machine carefully, write your conclusions as to why you believe it would or would not produce continuous motion. Record in your notebook.*

Exercise. *By reference to other books see how many ideas and drawings for perpetual motion devices you can find. Study them and see if you can find the reason that they will not work.*

FIG. 232. PERPETUAL MOTION DEVICE

Though man has been lured by the appeal of creating a machine that, once set in motion, would never stop, our present understanding of the principles that control perpetual motion in a mechanical device would seem to indicate that it is not possible. Whenever moving parts of a machine touch, there is friction, and to overcome this friction energy from some outside source must be supplied. This seems to be the difficulty with most of the schemes proposed. In many instances models have been made in which the friction has been reduced to the very lowest point, and the machine would seemingly run on forever, but after while the friction overcomes the motion and the machine is stopped. Even today hardly a year goes by that the United States Patent Office does not receive drawings of fantastic mechanical devices for the accomplishment of continuous motion.

What are the advantages and disadvantages of friction? Friction is a force which both aids and hinders us. A person walking on an icy pavement welcomes the increased friction of sand or cinders. An automobile is prevented from slipping on wet pavements by the treads on the tires and on icy pavements by chains. The locomotive engineer puts sand on the tracks when they become wet or slippery. These are aids of friction. On the other hand, in the automobile and every other modern machine man tries to reduce friction. Wherever moving parts of a machine touch there is friction which tends to slow down the machine and make it run harder. A new automobile must not be driven fast for the first five hundred miles. This is because the moving parts of a new car are so tight that the great heat produced by friction might cause damage to them.

Exercise. *We have industries whose efforts are devoted to increasing friction and others devoted to reducing it. Can you give examples of both kinds of industry.*

What causes friction? If you were to examine even the smoothest surfaces with a powerful microscope you would find that actually they are not smooth at all, but quite rough. When two such sur-

faces are put together, the tiny irregularities seem to fit together. They hook on to one another and thus resist any tendency for one surface to slide over the other one. This is illustrated by Figure 233.

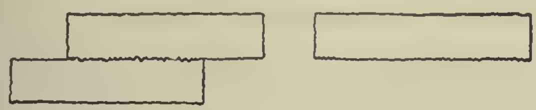


FIG. 233. EVEN SMOOTH SURFACES ARE ROUGH

There are two kinds of friction. Everyone knows that it is much easier to draw a cart than to draw a sled over a pavement. The reason for this is that with the sled we are dealing with sliding friction and in the wagon with rolling friction. In the first case the surface irregularities slide over each other and show

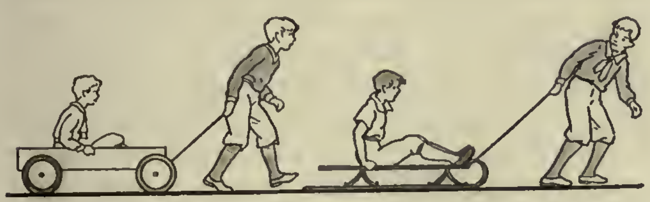


FIG. 234. ROLLING FRICTION IS LESS THAN SLIDING FRICTION

a greater tendency to hook and resist. In the case of rolling friction in the cart there is less surface in contact with the pavement to begin with, and then the surfaces tend to roll or slip by each other with less chance for the little projections of one surface to hook to those of the other.

Friction helps us in many ways. If our shoes did not have friction with surfaces we should be unable to walk or run. In playing athletic games in the gymnasium we use rubber-soled shoes because they have greater friction with the floor. Football and baseball players wear shoes with projections on the bottom, which tend to increase the friction with the earth and prevent the athlete from slipping. Wherever power is transmitted from one pulley wheel to another by means of a belt it is made possible only by the friction of the belt with the pulley. In the automobile, besides the use of friction in the tire treads and chains, it is used in the clutch and in the brakes. Friction is used so much in the brakes to stop the automobile that we must frequently have new asbestos linings put in them to increase the friction and make them safer.

Man has learned how to reduce friction. Wherever moving parts of machines which are doing useful work rub together, friction is a hindrance. Great industries have been built up in an endeavor to reduce the hindrance of friction to the lowest possible point. One of the best ways to reduce friction is by lubrication with some substance such as oil. This tends to fill the little irregularities in the surface and keep them from hooking on to each other. If you have ever tried to push a lawn mower before and after oiling, you know how much harmful friction can be reduced. The oil industry is maintained partly by man's endeavor to reduce friction.

FIG. 235. ROLLER BEARINGS

The fact that rolling friction is less than sliding friction has led to the development of another great industry. This is the roller and ball bearing industry. The use of little rollers and balls, made of hard steel, between surfaces which are in contact, greatly reduces the amount of friction. In Figure 235, which shows roller bearings, you will notice that the rollers are held in frames.

Friction is usually associated in our thinking with hard surfaces, but in recent years air friction has come to play an important part in transportation. Automobiles, buses, and trains have adopted streamlined designs which tend to reduce air friction and thus make possible greater speeds. Airplanes also

Courtesy Chrysler Corporation

FIG. 236. STREAMLINED AUTOMOBILE

have been streamlined to reduce air friction, and planes are now flown at greater altitudes where the air is less dense and therefore produces less frictional resistance to retard the planes. Figure 236 is a picture of a modern streamlined automobile.

Why do substances have weight? Weighing is one of the most important activities in which we engage

in modern life. Almost all the food we buy is purchased on the basis of its weight. It is also true of many of the other necessities of life. In spite of the fact that we use weighing so much, not many persons could give a really scientific answer to the question of this problem, "Why do substances have weight?" From your everyday experience you are acquainted with many of the facts which will help you answer this question if you can put them together in the right manner. Everyone has thrown stones or baseballs into the air and observed that no matter how hard they are thrown they always return to the earth. Even the shells from cannons propelled at tremendous velocities and things released from airplanes and balloons fall soon to the earth.

Over two hundred fifty years ago Isaac Newton, one of the greatest thinkers of all time, was pondering over this same question, "Why do substances have weight?" and with his keen ability to think clearly and see the causes for certain phenomena, he was able to offer an explanation which is as acceptable today as it was when he first proposed it long ago.

Newton believed that every body in the universe attracts every other body with a certain force. That is, when a ball is thrown into the air it pulls on the earth and the earth pulls on it with a certain force. The ball seems to fall toward the earth, but really the earth moves up a little way to meet the ball. However, the earth pulls so much harder on the ball than the ball can pull on the earth that the ball moves farther toward the earth than the earth does toward the ball, before they meet.

FIG. 237. THINGS FALL TO EARTH

Why should the earth pull harder on the ball than the ball on the earth? Newton believed that this attractive force which exists between bodies and which he called *gravitation* was due to the amount of material in a body, or its *mass*. Therefore the earth, having greater mass than the ball, exerted the greater gravitational pull of the two.

Newton with his genius applied this principle of gravitation to explain why the planets and other bodies of the solar system follow fixed orbits or pathways about the sun.

But what has this force of gravity to do with the weight of substances? Everything! The weight of any body is merely the measure of the pull of gravity for that substance. When you step on a pair of scales you are measuring the extent to which the force of gravity is pulling you to the earth. Things have weight because gravity is pulling on them. If one could travel outward in space to a point about 160,000 miles from the earth toward the sun, the force of gravity of the sun pulling the earth would be exactly equalled by the force of gravity of the earth pulling the sun. At this point things would have no weight.

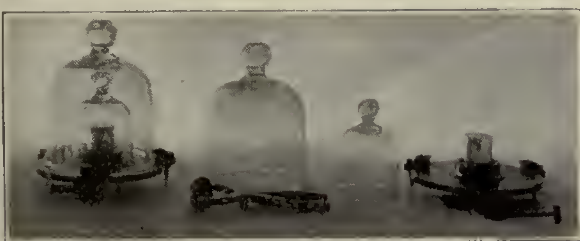
Exercise. *Can you suggest some of the effects if the force of gravity were suddenly to disappear?*

The weight of a substance is determined by comparing it with a standard of weight that has been determined according to some system. Figure 238 shows a photograph of the standard of weight maintained at the Bureau of Standards in Washington, D.C. This is the standard kilogram, a unit of weight used in the metric system, and it is equal to 2.2046 pounds. Weights for use with weighing devices are checked with this or other standards.

Two types of scales are used to determine the weights of substances, one known as the spring scale and the other known as the platform scale or balance. In using the spring scale the weight of an object is read directly from the scale, which has been marked off by using standard weights on it. In the use of the platform balance the weight of an object is determined by comparing it with or balancing it against a set of weights. Since the force of gravity pulls equally on bodies that have equal mass, when the scales are in equilibrium the weights of the bodies are equal and the weight of the body being weighed may be determined from the total of the known weights.

Bodies do not weigh the same at all places on the

earth. The earth is not a perfect sphere. Because of the centrifugal force resulting from the spin of the earth on its axis, it bulges at the equator and is flattened at the poles. Hence the poles are a little closer to the center of the earth than the equator, and the force of gravity is consequently greater at the



Courtesy Bureau of Standards, U. S. Dept. of Commerce

FIG. 238. STANDARD KILOGRAM

poles. The farther away from the center of the earth a place on the surface is, the less is the attraction of the force of gravity and therefore the less substances will weigh. However, this difference is very slight and for all practical purposes of weighing may be neglected.

Exercise. *It is not possible to detect the difference in the gravitational pull between the equator and the poles with a platform scale and a set of weights. It may be detected, however, with a spring scale. Explain why this would be true. Record in your notebook.*

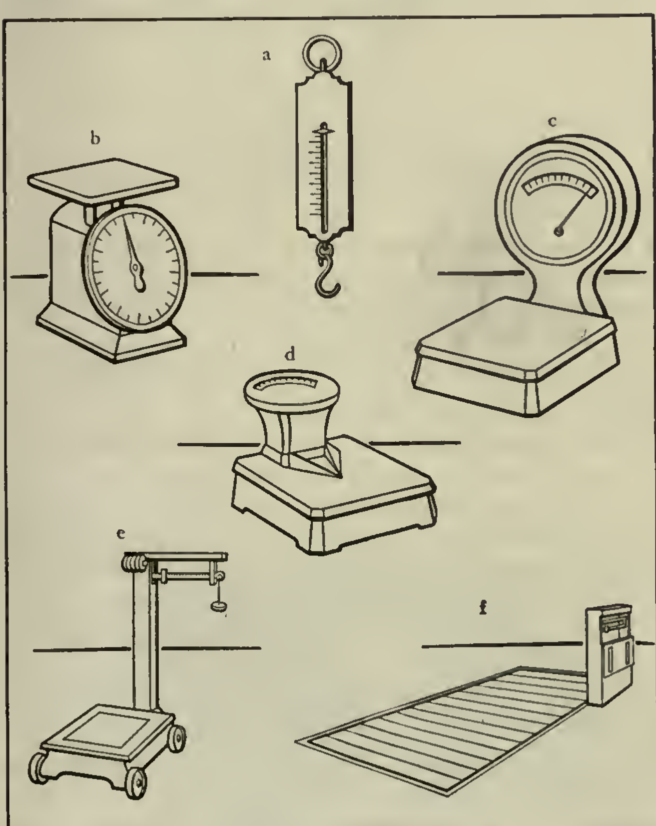


FIG. 239. SCALES IN DAILY LIFE

a. Spring balance
b. Household spring balance
c. Grocer's scales
d. Bath scales
e. Truck scales
f. Platform scales

What are the systems for measuring weight? Several systems of weighing are used in this country,

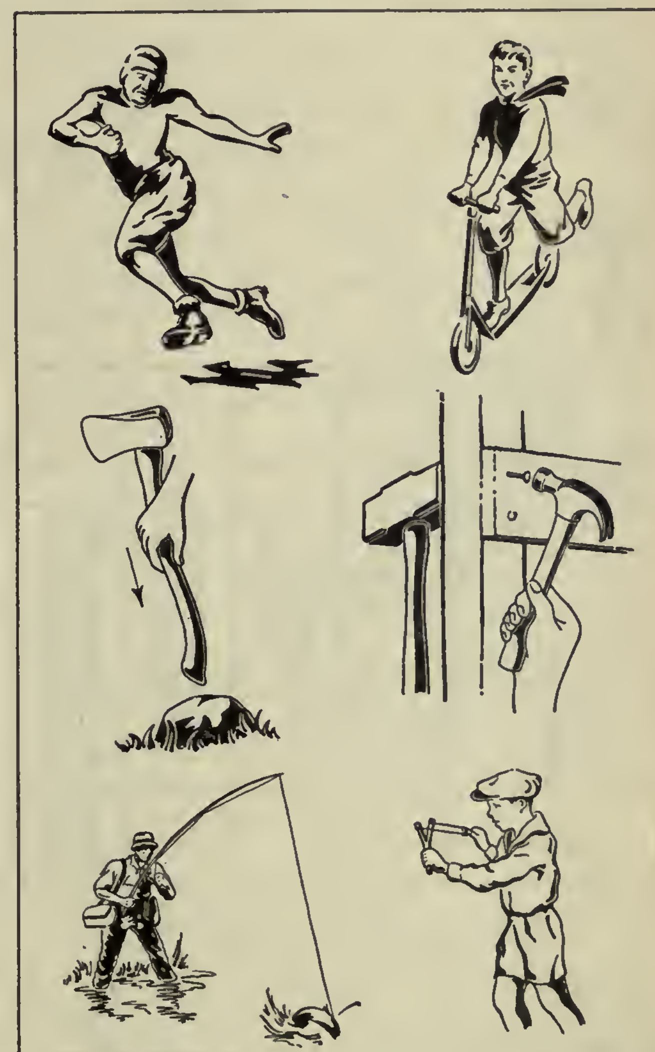


FIG. 240. INERTIA IN OUR DAILY LIFE

two of which are important for general knowledge. These are the commonly used English system, and the metric system used mostly in scientific work. The units in the English system which are used most are the ounce, the pound, and the ton; in the metric system they are the gram, the kilogram, and the metric ton.

The metric system of weights is better adapted for scientific work because it is a decimal system. The fundamental unit, the gram, is defined as the weight of one cubic centimeter of water at 4 degrees centigrade. The gram is a very small unit amounting to about 1/28 of an English ounce. There are 454 grams in a

pound and 2.2046 pounds in a kilogram. The metric table of weights is as follows:

10 milligrams	=	1 centigram
10 centigrams	=	1 decigram
10 decigrams	=	1 gram
1000 grams	=	1 kilogram

In Experiment 105 you found that equal volumes of different substances weigh different amounts. For example, lead will weigh eleven times as much as the same volume of water, and aluminum about 2.56 times as much as an equal volume of water. The weight of a unit volume of any substance is known as its *density*. Density is an important factor in scientific work because it provides one way of determining the purity of substances. Density is expressed as a decimal or as

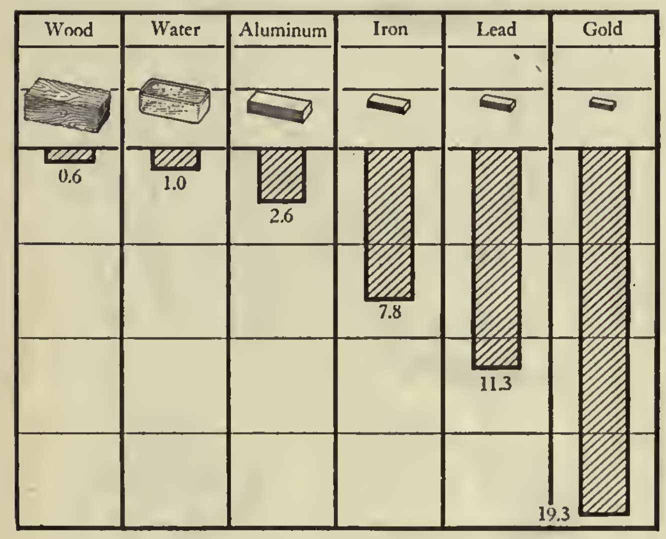


FIG. 241. EQUAL WEIGHTS OF DIFFERENT SUBSTANCES HAVE DIFFERENT VOLUMES

Density is the weight of a unit volume of any substance.

a whole number. Figure 241 shows the densities of some common substances.

Why does one pitch forward in a car that is suddenly stopped and why are turns on railroads and highways banked? No doubt you have wondered why these two questions were asked in one problem, and you will certainly be surprised to learn that they are closely related; in fact, their causes are identical. The cause is the inertia of bodies.

Inertia is a property possessed by all bodies that tends to make them remain as they are. If they are in motion, inertia tends to keep them in motion in a straight line, and if they are at rest, inertia tends to keep them at rest. Perhaps you have seen a sleight-of-hand performer remove the tablecloth from a table set with dishes without disturbing them. By giving the tablecloth a quick pull he sets it in motion, but the inertia of the dishes leaves them undisturbed.

If you have ever been riding in an automobile or train that is suddenly stopped, you have observed the tendency of a body to remain in motion when suddenly stopped. And when the automobile or train is suddenly started, the inertia of your body while at rest causes you to be jerked backward. You use inertia when you pick one book from under a pile or when by a sudden jerk you remove a board from under a pile of other boards.

We make many other uses of inertia in daily life. Often the head of a hammer, or a pick, is driven on to the handle by pounding the end against a stone.

FIG. 242. AN EXAMPLE OF INERTIA

The boy removes the tablecloth with a sudden pull.

The force of the blow sets the whole body in motion. The motion of the handle is stopped by the rock, but the inertia of the head tends to continue its motion and thus drive it more tightly on the handle.

Exercise. *Infer a cause or reason based on the above study for each of the following:*

1. *A person tends to feel lighter for a moment when an elevator suddenly starts downward, and heavier when it suddenly starts upward.*
2. *A heavy hammer or weight is often placed behind a springy board into which a nail is to be driven.*
3. *Rugs are shaken to remove dust and dirt.*
4. *It is unsafe to step from a moving street car or automobile.*

If a body is in motion its inertia tends to keep it moving in a straight line unless some other force acts to change this direction. An automobile turning a curve on a slippery pavement often skids. This is an example of the tendency to remain in motion in a straight line. In Experiment 107 you learned that when you whirled the weight on the string and then let go the string the weight flew outward in a straight line. This tendency of whirling bodies to fly outward

is known as centrifugal force. This word is made up from two Latin words *centri*, meaning center, and *fugere*, meaning to flee. The true meaning of the word is flee from the center.

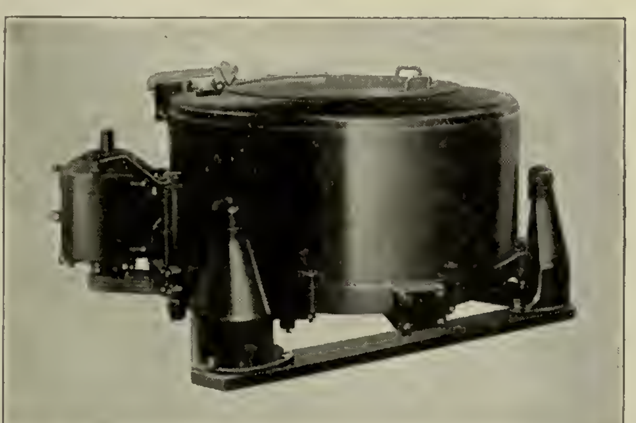
To keep bodies that are whirling or rotating from moving away from the center of rotation, it is necessary to apply another force to pull them in toward it.

International News Photos, Inc.

FIG. 243. BOBSLED BANKING ON A CURVE

You observed that in the experiment as you counteracted the centrifugal force by pulling on the string. When you replaced the string with the rubber band you could not apply this counteracting force because of the elasticity of the rubber band, and the weight pulled outward. This force which must be applied to keep bodies in a circular path is known as centripetal force. This word also is made up of the Latin words *centri*, center, and *petere*, to move toward. Its true meaning is moving toward the center.

The gravitational pull of the sun furnishes the centripetal force necessary to hold the planets in their orbits. Grinding wheels which are turned very fast must be made strong to supply sufficient centripetal force to keep them from flying apart.



Courtesy U. S. Hoffmon Machinery Corporation

FIG. 244. CENTRIFUGAL DRIER

The turns of highways and the curves of railroads are raised or banked on the outside, and when airplanes make a turn they must "bank." This banking tends to supply the necessary centripetal force to keep the automobile, the train, or the airplane in the curved path.

Considerable use is made of centrifugal force in daily life. In laundries and dry cleaning establishments centrifugal driers are used to free water and cleaning fluids from clothing. The clothes are placed in the drier which is rapidly whirled, and the liquid particles are thus thrown away from the clothes by centrifugal force. Cream is separated from milk in the dairy industry by centrifugal force. The milk is placed in a separator and rapidly whirled. The milk particles are heavier than the cream and so are thrown to the outside, where they are drawn off.

Courtesy DeLoval Separotor Co

FIG. 245. MILK SEPARATOR

This study of inertia and its effects has taught you one other very important fact about forces, that is, a force never exists singly. Forces always go in pairs. In the case of the car on the turn, the centrifugal force which would cause it to skid was counteracted by the centripetal force furnished by the banking of the curve. If you push against a wall, the wall pushes back against you with the same force. You have observed this tendency of forces to act in pairs when stepping from a boat to land. The boat is pushed backward as you push forward. Guns kick or recoil. When a gun is fired it is pushed backward with the same force that the bullet is pushed forward by the expanding gases.

How much distance must be allowed for stopping cars traveling at different speeds? In these days of high speed automobiles and trains, it is necessary that everyone who drives a car know something about the scientific principles involved in stopping. This is in the interest of safety.

When the automobile is started from rest it is speeded up by pressing on the accelerator. This admits a large amount of the gas and air mixture to the

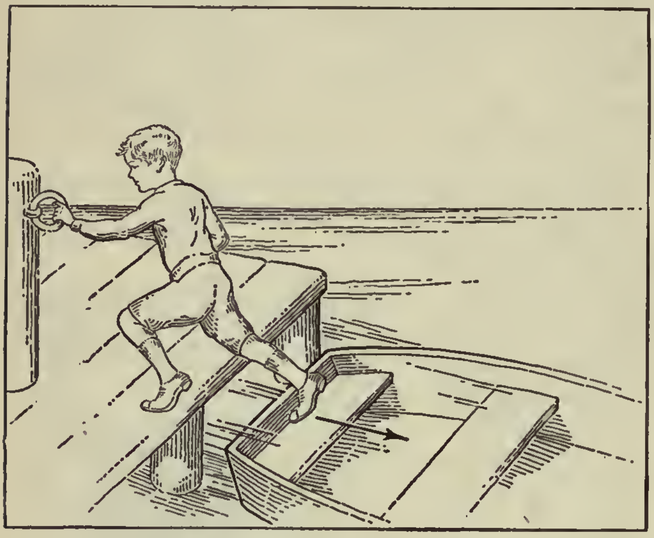


FIG. 246. BOY STEPPING OUT OF ROWBOAT

engine and thus the engine runs faster and is able to apply a greater force through the driving wheels. If the car is to accelerate, or speed up, the force applied

International News Photos, Inc.

FIG. 247. RECOIL OF A GUN

by the engine must be greater than the forces which are tending to hold the car back, such as air resistance and the friction of the parts in the mechanism of the car.

When the car gains speed it is said to *accelerate* and when it loses speed it is said to *decelerate.* If a car is traveling at thirty miles per hour, the engine has had to supply a certain force to accelerate to this speed. To stop the car the brakes must be able to supply the same retarding force as was applied by the engine to accelerate it.

The table on this page shows the distances that must be allowed for cars traveling at various speeds to stop.

Exercise. *Study the data carefully and then measure the average length of your step when stepping off a distance. Either in the hallway or outside, pace off the distances required by cars traveling at different speeds to stop.*

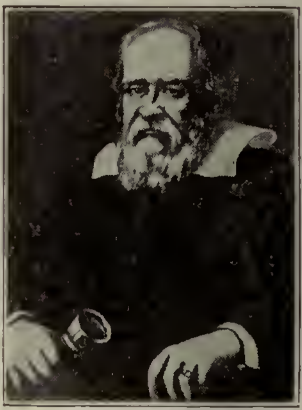


FIG. 248. GALILEO

Long ago it was thought that bodies which were free to fall through the air would fall at different rates, heavier objects falling faster than lighter ones. Galileo, the great Italian scientist, disproved this idea by dropping bodies of different weights from the Leaning Tower of Pisa, shown in Figure 249. Galileo believed and proved by experiment that since the force of gravity was constant at any given place on the earth, it would cause bodies to accelerate at the same rate.

TABLE OF STOPPING DISTANCES FOR AUTOMOBILES

Speed of Car in Miles per Hour	With Two-Wheel Brakes	With Four-Wheel Brakes
20	37 feet	17.4 feet
30	83 feet	39.2 feet
40	148 feet	69.6 feet
50	231 feet	108 feet
60	333.5 feet	156.5 feet

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of the reasons for the impossibility of perpetual motion.
2. A knowledge of the uses and hindrances of friction.
3. An understanding of the methods used to reduce friction.
4. An understanding of how the force of gravitation causes substances to have weight.
5. An understanding of the principle of inertia and its uses in everyday life.
6. An understanding of the principle that forces never exist singly but always in pairs.
7. An understanding of the principle that to accelerate a body a force must be applied and that to decelerate a body a force must be applied.

FIG. 249. LEANING TOWER OF PISA

REFERENCES FOR FURTHER STUDY

Caldwell and Curtis, *Science for Today*, Chap. 7
Clement, Collister, and Thurston, *Our Surroundings*, Chaps. 2, 6, 18
Hunter and Whitman, *Science in Our World of Progress*, Unit 8; *Science in Our Social Life*, Unit 8
Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 18
Pieper and Beauchamp, *Everyday Problems in Science*, Units 12, 13
Powers, Neuner, and Bruner, *This Changing World*, Chap. 2 (part), Chap. 19 (part); *Man's Control of His Environment*, Chap. 15
Skilling, *Tours through the World of Science*, Tours 8, 9
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 16
Watkins and Bedell, *General Science for Today*, Chap. 16
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 5
Wood and Carpenter, *Our Environment: How We Use and Control It*, Topics 2, 3, 10, 11

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Make a list of ten uses of friction.
2. Make a list of all the hindrances of friction that you can find.
3. Tell of one attempt at perpetual motion and why it would not work.
4. When mechanical energy disappears in friction, ____ energy appears.
5. Show three ways in which friction is made use of in the automobile and three ways in which it is a hindrance.
6. Friction is reduced in machines by means of ____ and ____ bearings and by ____.
7. What type of energy is being expended in Figure 220? Into what form of energy is this being changed? Give another example of this transformation of mechanical energy.
8. Ball and roller bearings are utilized in reducing friction because ____ is less than ____ friction.
9. Sand is of value on a slippery railroad or street because it increases ____ and decreases the danger of ____.
10. The gram is a unit of ____.
11. ____ is the amount of matter in a body.
12. The tendency of a body to remain at rest or in motion is called ____.
13. *Centrifugal* means ____ and *centripetal* means ____.
14. The force which holds the planets in their orbits is known as ____.
15. The ____ of a body is the measure of the pull of ____ for that body.
16. The gram is about ____ of an ounce.
17. The gram is defined as the weight of ____ of water at ____ degrees centigrade.
18. The ____ of a body is its weight per unit ____.
19. Two applications of centrifugal force in everyday life are ____.
20. Increasing the speed of a moving body is known as ____ while decreasing the speed is known as ____.
21. Forces never exist ____ but always in ____. An example of this is ____.
22. Galileo discovered that bodies which have different ____ fall at the ____.

TOPIC 2. THE MACHINES WE USE IN EVERYDAY LIFE

SUGGESTED PROBLEMS AND QUESTIONS

1. What is work and how is it measured?
2. What are the various types of levers and how do they aid us?
3. How do the different kinds of inclined planes help us do our work more easily?
4. How may machines be made more efficient?

SUGGESTIONS AND HELPS FOR STUDY

1. Collect and classify as many pictures of machines during this study as you can. See the advertisements in magazines and newspapers.

2. The lever and inclined plane are known as simple machines. All machines, regardless of how complicated they may be, are based upon one or both of these simple types.

3. Mechanical advantage is a term which may confuse the beginner. It refers to the number of times greater a load lifted or moved by a machine is than the force which one applies to the machine. For example, if one can move a 100-pound rock with a lever bar by applying ten pounds of force he has gained an advantage of 10 over the load or resistance.

4. You may find the following new words and phrases in this study.

efficiency—a percentage obtained by dividing the work got out of a machine by the work put into it.

$$\text{Efficiency} = \frac{\text{work out}}{\text{work in}}$$

energy—the capacity of a body to do work. A raised hammer has capacity for doing work and therefore possesses energy.

foot pound—a unit for measuring work. The number of foot pounds of work is found by multiplying the force in pounds by the distance moved in feet. If a two-pound weight is lifted four feet, then eight foot pounds of work have been done.

force—a push or a pull on a body.

~~*gear*~~—a wheel with teeth around the outside. It is a type of machine.

~~*mechanical*~~—having to do with machines.

fulcrum—the point about which a lever turns.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 108. What is the principle of the lever and how does the lever give an advantage in doing work?

Drive a nail through the midpoint of a yardstick or a piece of wood from thirty-five to forty inches in length which is marked off in inches. The nail should project on each side of the stick to form an axle when it is balanced between two wood blocks as shown in Figure 250.

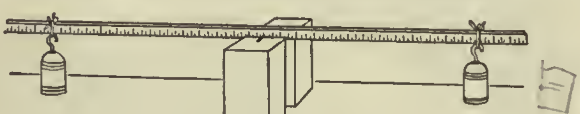


FIG. 250

Part 1. Either brass weights, as shown in the drawing, or small bags of sand which have been carefully made the same weight as those made of brass may be used. Place a one-pound weight on the right side of the lever bar at a distance of ten inches from the nail or fulcrum at the center of the stick. On the other side of the fulcrum place another one-pound weight at such a point that the lever will exactly balance. Observe the distance of each weight from the fulcrum and record your results. Remove the weights from the bar.

Part 2. Place a one-pound weight on the left side, six inches from the fulcrum, and a half-pound weight on the right side at such a point that it will balance the lever bar. Again observe the distance of each weight from the fulcrum and record in your notebook. Remove the weights from the bar.

Part 3. Place a one-pound weight on the left side of the fulcrum twelve inches away from it and a half-pound weight on the same side eight inches from the fulcrum. On the right side of the fulcrum place a one-pound weight at such a distance that the bar will balance. Carefully observe all the weights and their distances from the fulcrum.

[1] See workbook, p. 55.

Perform the simple calculations indicated below after you have recorded your results.

Part 1.

Weight on left of fulcrum = ____ pounds.
Distance of weight from fulcrum = ____ inches.
Weight × distance = ____.
Weight on right of fulcrum = ____ pounds.
Distance of weight from fulcrum = ____ inches.
Weight × distance = ____.

Part 2.

Weight on left of fulcrum = ____ pounds.
Distance of weight from fulcrum = ____ inches.
Weight × distance = ____.
Weight on right of fulcrum = ____ pounds.
Distance of weight from fulcrum = ____ inches.
Weight × distance = ____.

Part 3.

First weight on left of fulcrum = ____ pounds.
Distance of weight from fulcrum = ____ inches.
Weight × distance = ____.
Second weight on left of fulcrum = ____ pounds.
Distance of weight from fulcrum = ____ inches.
Weight × distance = ____.
Sum of products = ____.
Weight on right of fulcrum = ____ pounds.
Distance of weight from fulcrum = ____ inches.
Weight × distance = ____.

In this experiment, when a lever is in balance, the product ~~of the~~ ____ on one side of the fulcrum by its distance from the ____ must be equal to the product of the weight and its ____ from the ____ on the other side. When a weight is twice as great as another, the greater weight will be ____ as far from the fulcrum as the smaller. If two or more weights are on either side of the fulcrum, the ____ of the products of the weights and their distances from the fulcrum on one side must equal the ____ of the products on the other side if the lever is in balance.

Problem. A boy weighing 100 pounds wishes to raise a 400-pound weight with a lever bar by placing the weight on one end and standing on the other side of the fulcrum. If the lever is ten feet long, where should he stand to gain the needed advantage when the weight is one foot from the fulcrum?

Experiment 109. How do pulleys gain an advantage and how may this be found?

Read on page 161 the section "How may machines be made more efficient?" before doing this experiment.

Part 1. Hang a single pulley from a support as shown in Figure 251 at *A*. Thread a piece of strong string through it. To one end of the string attach a weight of one or two pounds and to the other a ten-pound spring balance. Raise the weight and read on the balance the number of pounds of force required to raise the weight. In raising the weight one foot, how far did the effort

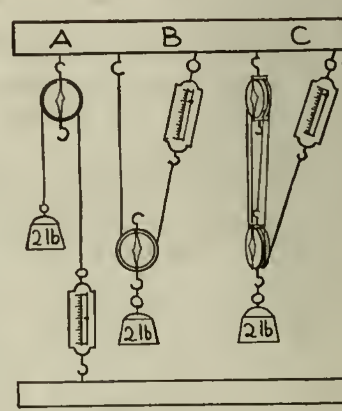


FIG. 251

force or balance travel? Record your results.

Part 2. Rearrange the pulley, weight, and balance to be like the diagram shown at *B* and repeat the measurements made in the first part. Record your results.

Part 3. Secure a pair of two-pulley blocks and set them up as shown in the diagram at *C*. Attach the spring balance as shown and a four-pound weight. Measure the effort needed to lift the four-pound weight and also weights of six and ten pounds. Measure the distance the effort force or balance moves vertically in raising the load half a foot. Record your results.

Make the simple calculations indicated.

Part 1.

Load = ____ pounds. Effort = ____ pounds.
Load distance = 1 foot. Effort distance = ____ feet.
Load × load distance = ____.
Effort × effort distance = ____.

Part 2.

Load = ____ pounds. Effort = ____ pounds.
Load distance = ____ feet. Effort distance = ____ feet.
Load × load distance = ____ foot pounds.
Effort × effort distance = ____ foot pounds.
The number of cords to the movable pulley = ____.

Part 3.

Tabulate the data for Part 3 under the column headings *Load, Effort, Load Distance, Effort Distance, Output,* and *Input.*

In a single fixed pulley the effort is (greater than, less than, the same as) ____ the load and therefore ____ advantage is gained.

The load distance is (equal to, greater than, less than) ____ the effort distance.

In a single movable pulley ____ cords support the load, and the effort is ____ the load. This gives an advantage of ____.

The advantage gained by a pulley system over a load can always be told by counting the ____ which ____ the load.

In this experiment the work put into the machine was found by multiplying the ____ by the ____. The work put out by the machine was found by multiplying the ____ by the ____. These were nearly ____ in all cases. The difference was due to ____. The work (put in, got out) ____ was always greater.

Experiment 110. How does the inclined plane gain an advantage and how may the advantage be found?

Read on page 161 the section on "How may machines be made more efficient?" before doing this experiment.

This experiment calls for a small car like the one shown in the picture, but a toy railroad car may be used in its place. If neither of these is available one can be made from a chalk box with spools for wheels. Secure a smooth board at least three feet in length and raise one end of it six inches from the table top. Weigh the car accurately and then place a one-pound weight or a one-pound bag of sand in it. Attach a string and spring balance to the car as shown in Figure 252. Determine the average force used to pull a one-pound weight and the car up the plane. Keep the balance parallel to the plane. Repeat, using weights of two and three pounds. Measure the length of the plane along its bottom edge up to the support and the height from the table top to the bottom of the plane at the support. Record your measurements and calculations in a table under the column headings *Weight of Car, Load, Total Load, Effort, Length, Height, Input (Length × Effort), Output (Total Load × Height).*

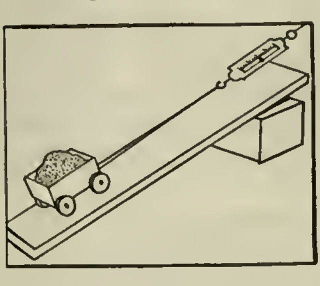


FIG. 252

Make the height of the plane one foot and repeat all of the measurements made in the previous case. Record your results.

Study the two data tables. How does the effort change with the increased load? How does the effort change with the increased height? What is the ideal mechanical advantage in each of the two cases? To find this, divide the length of the plane by its height. What is the actual mechanical advantage in each of the two cases? To find this, divide the load by the effort. Can you account for the difference?

How does the work put into this machine (effort × length) compare with the work got out of it (total load × height)? Why is there a difference?

Determine the efficiency of this plane from each of the two parts. (Divide the work got out by the work put in.)

Problem. A man wishes to raise a heavy box into a truck. He can use either a long or a short plank as an inclined plane. State what he would gain and lose in the use of each.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is work and how is it measured? We are living in an age of machines. During the past two hundred years the world has been changed from a "hand" world to a "machine" world. Today we ofttimes prize the word "hand-made" on articles that we purchase. Shall we live to see the "hand-made" a completely lost art? Our farmers no longer farm with the hand plow, the scythe, and the cradle of a few generations ago. These farming implements have been replaced by the gang plow, the mowing machine, and the reaper. Even the horse, man's faithful servant, is rapidly being replaced by the tractor.

In the home we now perform with machines many tasks formerly done by hand. Our means of transportation have been changed by the introduction of the automobile and airplane. It is no wonder that this is called the "machine age."

With all of their complexity, modern machines are really only combinations of two very simple machines which have been known to man for many ages. These are the lever and the inclined plane. By combining these into intricate and involved machines man has been able to overcome many of the resisting forces of nature.

Machines are able to help us in modern life because they aid us in applying force and in gaining speed. In the use of machines to conquer the forces of nature, the scientist has learned how to measure the work done by machines. Let us see how he accomplishes this.

The usual conception of work is different from the scientist's idea of work. When one is tired he says that he has been working hard. From the scientist's point of view he may not have done work at all. If, for example, you were to push on a large building, trying to move it, the end of a day would find you very tired. You would think that you had done a hard day's work, but a scientist would say that unless you moved the building no work was accomplished on it. From his point of view, to do work an applied force must move something, and the amount of work is measured by the amount of the force applied and the distance the object is moved. Since we measure the distance moved in feet and the force applied in pounds, the unit of work is called the *foot pound.*

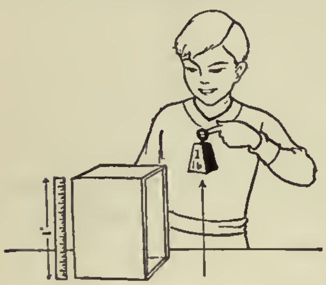


FIG. 253. DOING ONE FOOT POUND OF WORK

Work (foot pounds) = distance (feet) × force (pounds).

If, for example, a one-pound weight is raised through a distance of one foot, one foot pound of work has been done (see Fig. 253).

Problem: How many foot pounds of work would be done by an engine raising 400 pounds of concrete to the upper stories of a building 200 feet above the street?

What are the various types of levers and how do they aid us? Levers have been known since early times. It is difficult to say when and where the lever was first known, but early man must have used it to move heavy stones and logs and to provide handles for his stone axes and hammers. The principle of the lever was probably first explained by Archimedes, a Greek scientist and mathematician who lived in the city of Syracuse, in Sicily, from about 287 to 212 B.C.

Archimedes discovered that all levers are essentially the same and have the same forces working on them. A lever is usually a straight bar but may be bent for special purposes. The see-saw which is a part of every child's experience is an example of a simple lever. By studying the see-saw we shall be able to learn the principle which Archimedes discovered.

If you can remember your "see-saw" days you will recall that the board was first balanced on the saw horse or log. This point of balance is found in all levers and is called the *fulcrum.* Now if your companion and you were of the same weight, you placed yourselves at the same distance from the saw horse, or fulcrum. If, however, you were heavier, it was necessary for you to get closer to the fulcrum and your companion farther away on the other side. When the see-saw was exactly in balance, how easily it moved up and down and what fun you had! Now let us study the see-saw a little more closely and find out some things about it which you may not know.

Suppose you have balanced the board. Your weight is 100 pounds and your companion's weight is 80 pounds. You already know that he must be farther away from the fulcrum than you, but how much

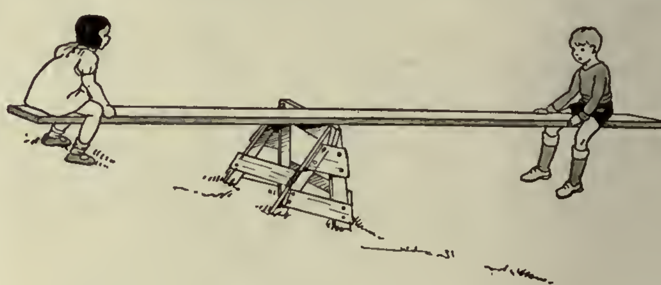


FIG. 254. "SEE-SAW" DAYS

farther away is a question. The board is ten feet long, and your companion sits on the very end. Where must you sit to balance him? Here is where you can use the discovery made by Archimedes. Archimedes found that *when the lever is in balance the weight on one side of the fulcrum multiplied by its distance from the fulcrum must exactly equal the weight on the other side multiplied by its distance.* Study Figure 255. Can you tell how far the second boy is from the fulcrum? What is the distance from the fulcrum that you would have to sit on the see-saw to balance your companion?

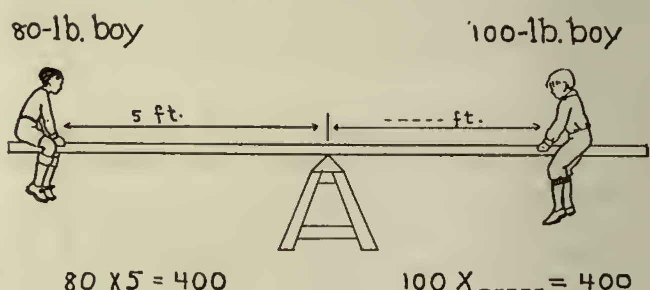


FIG. 255

Not all levers are exactly like the see-saw. They are different because the fulcrum and the two forces are not placed in the same position. Levers with the forces and fulcrum arranged as in Figure 256 are called the first-class levers.

If the fulcrum is on one end of the bar, and the weight anywhere between the fulcrum and the force working on the other end of the bar as shown in Figure 257, the lever is said to be of the second class. You are no doubt familiar with many examples of this type of lever, such as the wheelbarrow.

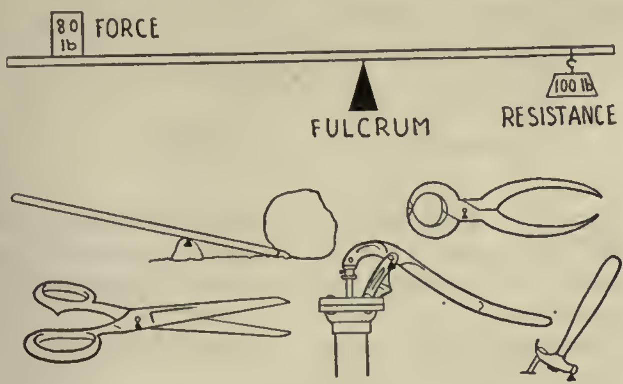


FIG. 256. LEVERS OF THE FIRST CLASS

In some levers the fulcrum is found at onc end of the bar, the weight or resistance on the other end, and the effort between them. A common example of this class of lever is the sugar tong. Figure 258 shows

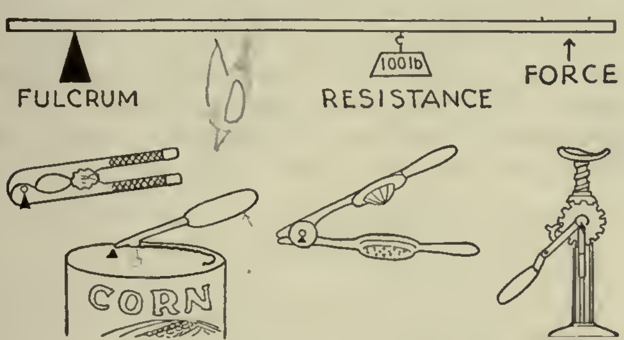


FIG. 257. LEVERS OF THE SECOND CLASS

the arrangement of the forces and also suggests other examples. The arrangement of the forces acting does not affect the application of the discovery of Archimedes. The effort force multiplied by its distance from the fulcrum always equals the weight multiplied by its

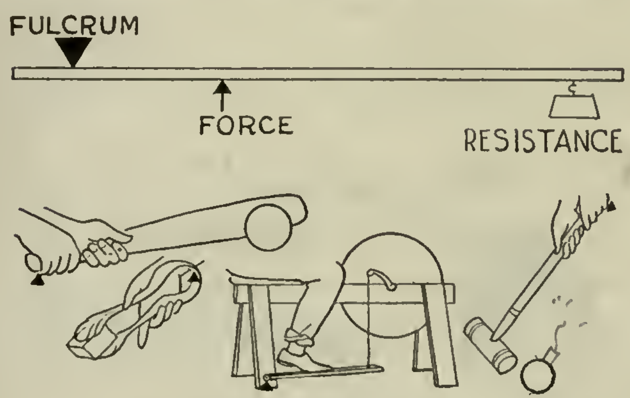


FIG. 258. LEVERS OF THE THIRD CLASS

distance from the fulcrum if the lever is in balance.

Sometimes the lever is bent; that is, the effort force, fulcrum, and weight are not in a straight line. In this case the shortest distance from the fulcrum to the point at which the forces are acting is taken. A good example of a bent lever is a hammer when used for pulling a nail. Figure 259 will illustrate this.

FIG. 259

The windlass is a lever. The windlass, or wheel and axle, as it is sometimes called, is made up of a crank which turns a smaller axle attached to it. A common example of this special lever was formerly much used to raise buckets of water from wells. In modern life we find many uses for the wheel and axle. Can you suggest any? Figure 260 shows that the wheel and axle is a lever. The fulcrum is at the common center of the wheel and axle. It is marked *F* in the diagram. The weight hangs at the rim of the axle, and the distance from the fulcrum is always the radius of the axle, marked *r* in the diagram. The effort is applied at the rim of the wheel, and this distance from the fulcrum is always the radius of the wheel, marked *R* in the diagram. When the machine is in balance as shown, the effort × the wheel radius = resistance × the axle radius.

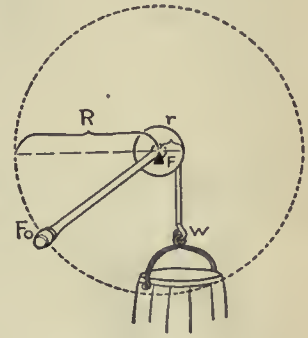


FIG. 260. WHEEL AND AXLE

Can you explain why this is true? One can tell how heavy a weight can be lifted with a certain effort force *by dividing the wheel radius by the axle radius.*

The pulley is also a lever. Pulleys are of two kinds: those which are fixcd or attached to something solid, and those which are movable. In order to gain an advantage of force over a resistance, some form of movable pulley must be used. A study of the fixed and movable pulleys in Figure 261 will teach you how the pulley is a special kind of lever.

The fixed pulley is a lever like the see-saw lever when two people of equal weight are balanced. The fulcrum is at the center of the pulley marked *F* in the diagram. The effort is applied on one side of the pulley and the weight is raised on the other side. In each case the distance from the fulcrum is the same and is always the radius of the pulley. In using a pulley of this type one must apply an effort which is a little greater than the weight to be lifted. The only gain is a change of direction in applying a force. Thus horses are driven along a roadway and are hitched to a hay fork which rises into the barn. The change of direction is made possible by the use of fixed pulleys.

The single movable pulley is a lever of the second class. Here the weight is attached to the center of the

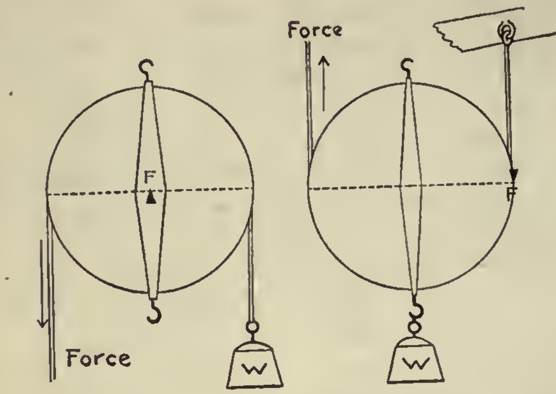


FIG. 261. THE PULLEY IS A LEVER

pulley. The fulcrum is where the pulley turns up the fixed rope, and the effort is applied on the other rope. Since the diameter is always twice the radius, it will be seen that with this machine one can always lift a weight which is twice as great as the effort force.

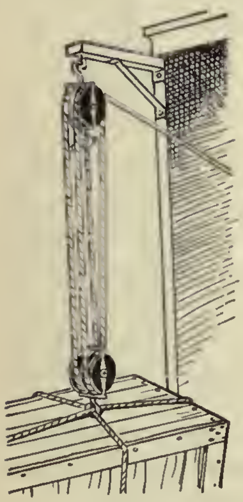


FIG. 262. BLOCK AND TACKLE

Sometimes pulleys are combined into blocks where two or more pulleys make up a single block. These are known as *block and tackle*. Figure 262 shows how a four-strand or double block and tackle is used to lift a weight.

There would probably be little need for machines if through their use man were not able to do his work more easily or more rapidly. The advantage gained over nature by using a machine is called *mechanical advantage*. This may be an advantage of either force or speed. The lever is an excellent example of these two kinds of advantage. In the first-class lever if the resistance distance is less than the effort distance, the advantage is one of force, while if the effort distance is shorter, the advantage is one of speed. Whenever speed is gained more effort force than the resistance must be applied. When force is gained it is at the expense of speed. In the second-class lever one can never gain speed. The only advantage to be gained is power. Can you explain this. What is the greatest resistance distance possible in this type of lever? In the third-class lever, it is impossible to gain an advantage of force. Only speed can be gained by its use. Can you explain the reason for this?

Mechanical advantage can be calculated in a simple lever by *dividing the longer lever arm or distance by the shorter one.* The practical or working mechanical advantage of any machine takes account of friction and may always be found by dividing the resistance force by the effort force.

$$\text{Mechanical advantage} = \frac{\text{resistance}}{\text{effort}}.$$

To find the mechanical advantage of the wheel and axle it is necessary only to divide the radius of the wheel by the radius of the axle, since these are the lever arms.

$$\text{Mechanical advantage of wheel and axle} = \frac{\text{wheel radius}}{\text{axle radius}}.$$

In the simple fixed pulley the mechanical advantage is one, since the lever arms are equal. In the single movable pulley there is always an advantage of two, since the resistance arm is the radius of the pulley and the effort arm is its diameter. To find the mechanical advantage of any pulley system, count the number of strings supporting the movable pulley. This is two in the single movable pulley, four in the four-strand block and tackle, and so forth.

Mechanical advantage of pulley system = number of cords supporting movable pulley.

How do various types of inclined planes help us do our work more easily? The inclined plane consists, in its simplest form, of a board by use of which heavy objects can be moved from one level to another. For example, in raising a heavy barrel into a truck less effort force is required to push it up an incline than to lift it vertically. It is probable that the Egyptians, in constructing the pyramids, built long inclines up which the massive stones were drawn by slaves. As the pyramid rose higher and higher, the inclines were doubtless made longer and longer. Figure 252 shows a simple inclined plane and Figure 263 shows how it is used in modern life.

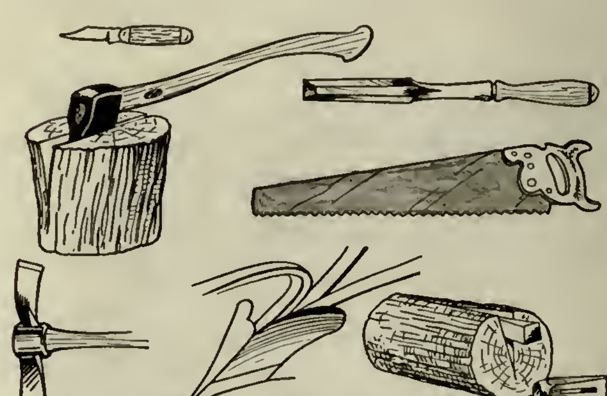


FIG. 263. COMMON USES OF THE INCLINED PLANE

There are four important parts in the simple inclined plane: the length, the height, the weight, and the effort. Experiment shows that the mechanical advantage of an inclined plane may be found by dividing the length by the height.

$$\text{Mechanical advantage of an inclined plane} = \frac{\text{length}}{\text{height}}$$

The wedge and the screw are inclined planes. Just as the wheel and axle and pulley make up two special kinds of levers, so the wedge and the screw make up two special kinds of inclined planes. The wedge forms a double inclined plane and is used in splitting logs and in many other everyday situations. The screw is a spiral inclined plane and finds many uses in everyday life, such as the wood screw, the bolt and nut, the food chopper, and the builder's lifting jack. You can see how the screw may be formed from the simple inclined plane by cutting a piece of paper in the form of a right triangle about four inches high and twelve inches long as shown in Figure 264. Beginning away from the point, roll this on a round stick and see how the length of the plane spirals to make the threads. Keep the bottom edge even.

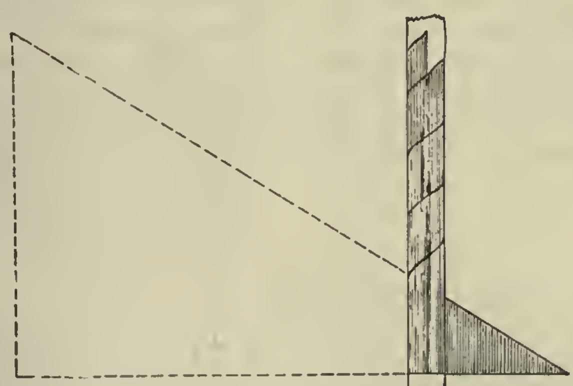


FIG. 264. THE SCREW IS AN INCLINED PLANE

Figure 263 shows the uses of the wedge in everyday life. Can you explain why a plow, a knife, an axe, and a saw are inclined planes?

How may machines be made more efficient? Simple and complex machines are used by man to give him an advantage in applying forces, but they do not make the work done any less. More work is always put into a machine than is obtained from it. In the block and tackle, if there are four cords supporting the load, one applies an effort force which is only one fourth the load being raised, but the effort force must move four times farther than the load force so that the work put in (effort force × effort distance) just equals the work put out by the machine (resistance force × resistance distance) if friction be neglected. Suppose, for example, that a twenty-pound weight is to be raised with a four-strand block and tackle. Experiment will show that if the load is raised one foot the effort force will move four feet but will be only one fourth of the load, or five pounds. The work put in and got out would then be found to be

Effort	×	effort distance	=	work in.
5	×	4	=	20 foot pounds.
Resistance	×	resistance distance	=	work out.
20	×	1	=	20 foot pounds.

In the inclined plane the work put into the machine is found by *multiplying the effort by the length of the plane.* The work got out of the machine is obtained by *multiplying the resistance by the height of the plane.*

Work in = effort × length.

Work out = resistance × height.

The work obtained from any machine is always less than that put in because some of the effort force is required to overcome the friction in the machine. Man is constantly trying to overcome friction. The next topic will tell you more about this.

Reducing friction increases the efficiency of machines. A machine which has a large amount of frictional resistance must use much of the work put into it in overcoming this friction. A machine which has little frictional resistance can produce more useful work. Machines are rated on their ability to turn the work put into them into useful work or output, and the rating is called *the efficiency of the machine.* It is obtained as a percentage by dividing the output in work units by the input in work units and multiplying by 100.

$$\text{Efficiency} = \frac{\text{Output (foot pounds)}}{\text{Input (foot pounds)}}$$

Suppose an inclined plane ten feet long were used in rolling a 200-pound barrel of flour into a truck three feet high. Assume the force required to push the barrel up the incline as seventy pounds; then

Input = length × effort = 70 × 10 or 700 foot pounds.

Output = weight × height = 200 × 3 or 600 foot pounds.

Efficiency = output/input = 600/700 = 6/7 = 85.7%.

Machines can never be 100 per cent efficient because of friction. That is, we must always put more work into a machine than we can get out of it. This makes perpetual motion in a mechanical device impossible.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 9

Clement, Collister, and Thurston, *Our Surroundings*, Chaps. 2, 6, 18

Hunter and Whitman, *Science in Our World of Progress,* Unit 8; *Science in Our Social Life,* Unit 8
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 18
Pieper and Beauchamp, *Everyday Problems in Science,* Units 12, 13
Powers, Neuner, and Bruner, *Man's Control of His Environment,* Chap. 16
Skilling, *Tours through the World of Science,* Tours 8, 9
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 16
Watkins and Bedell, *General Science for Today,* Chap. 17
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 5
Wood and Carpenter, *Our Environment: How We Use and Control It,* Topics 2, 3, 10, 11

Special references

Bond, *The American Boys' Engineering Book*
Bond, *With the Men Who Do Things*
Burns, *The Story of Great Inventions*
Darrow, *The Boys' Own Book of Great Inventions*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The ability to recognize and classify the simple machines.
2. A knowledge of the lever principle and how to make simple calculations involving it.
3. A knowledge of the work principle. How to calculate the work done by, and the efficiency of the various simple machines.
4. A knowledge of the way to find the mechanical advantage of the various simple machines.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Work is measured in ____.

2. How may the mechanical advantage of a simple straight lever be found?

3. The efficiency of a machine is found by dividing the ____ by the ____.

4. The common household food chopper is a combination of what two simple machines?

5. Make a list of six household devices which are levers.

6. What is the mechanical advantage of a single fixed pulley as shown in the diagram in Figure 261?

7. How may the mechanical advantage of a wheel and axle be found?

8. Make a list of five household devices which are inclined planes.

9. How may the mechanical advantage of an inclined plane be found?

10. Name two forms of the inclined plane.

11. The mechanical advantage of a pulley system may be found by counting the ____ of ____ supporting the ____.

12. State the lever principle in your own words.

13. State the work principle in your own words.

14. Make a list of the uses of simple machines in the automobile. Tell what type each is (lever or inclined plane).

15. Make a list of five examples of the screw.

16. What type of simple machine is each of the following: scissors, knife, automobile jack, gangplank for a ship, automobile crank, axe, crowbar, chisel, wheelbarrow, shovel, broom, hammer, fish pole, door, gear wheels, fruit jar top?

TOPIC 3. HARNESSING THE ENERGY ABOUT US

SUGGESTED PROBLEMS AND QUESTIONS

1. **How is the energy of coal harnessed and controlled?**
2. **How is the energy of gas and oil made available?**
3. **How is the energy of falling water harnessed?**
4. **What is the source of the energy about us?**

SUGGESTIONS AND HELPS FOR STUDY

1. Trace all the types of energy back as far as you can; for example, the light energy of the bulb comes from the electrical energy of the generator, which comes from the mechanical energy of the steam engine, and so on back.

2. All the various sources of energy which occur in nature should be carefully studied, such as coal resources, oil resources, water power, wind power, and harnessing the tides.

3. These problems deal with many common devices such as stoves and burners, electric cooking and heating devices, electric lights and gas light, motors and dynamos, steam engines and turbines and water wheels. Study each one carefully and understand how it converts energy from one type into another.

4. You may find the following new words and phrases in this study.

potential energy—stored-up energy or energy due to the position of some object.

kinetic energy—energy which a body has because of its motion.

turbine—a special type of wheel used to harness the energy of falling water or steam.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

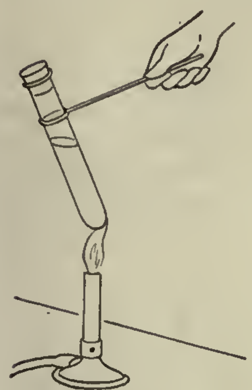


FIG. 265

Experiment 111. Where does steam get its energy?

Grease a solid rubber stopper which fits into a test tube. Place about a half inch of water in the test tube and insert the rubber stopper, but do not push it in very tightly. Place the test tube in a holder and hold over a flame. Point the stopper away from you and observe results.

The stopper was ____ the test tube. The force causing this came from the ____ of the steam. The steam secured its energy from the ____ energy of the ____.

Experiment 112. How may the energy of steam be harnessed by the steam turbine?

Bend an eight-inch piece of glass tubing to a right angle and draw one end of it down to a jet. Insert the other end in a one-hole rubber stopper which fits into a flask of at least 500-cubic-centimeter capacity. From a piece of quarter-inch wood cut a circle four inches in diameter. With a coping saw cut little slots every inch around the circumference of this piece. These should be about a half inch deep. See *B* in Figure 267. Now from a can cut little pieces of tin of the shape shown at *C* in the illustration. These should be about an inch long, a half inch wide at the top, and a quarter inch at the bottom. Make as many of them as there are slots in your wheel, and put one in each slot. After they are securely fastened, bend each one slightly to form a cup as shown at *D* in the illustration. Bore a hole through the center of the wheel and place an axle of round wood in it. Fill the flask about half full of water and after inserting the stopper place it over a flame and allow the water to boil until a strong jet of steam comes from the tube. Mount your turbine so that the jet just touches the cups shown in Figure 266. Write a summary of how this experiment, performed on a large scale, might be used in doing useful work.

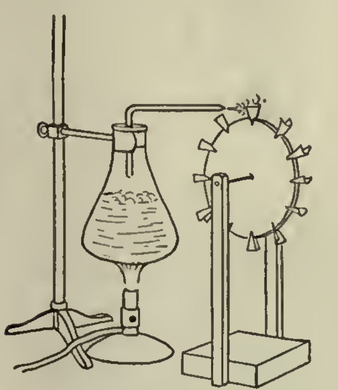


FIG. 266

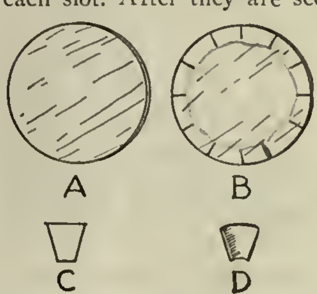


FIG. 267

Experiment 113. How may the energy of falling water be harnessed?

Using the same turbine which you constructed for the previous experiment, suggest and try out methods to illustrate each of the types of water wheels shown in Figure 279. Record your methods and results.

Experiment 114. How is the energy of steam harnessed by the steam engine?

This investigation will require reading from the references to answer the questions. Study Figure 268 carefully.

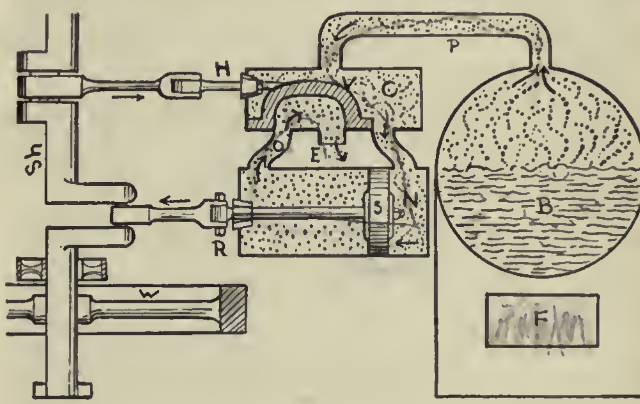


FIG. 268

All parts of the steam boiler and engine are shown. Be sure that you can tell what each part does, in the transformation of the heat energy of the coal to the mechanical energy of the flywheel, before attempting the exercises.

In your notebook complete the statements.

The steam engine transforms ____ energy into ____ energy. Four purposes for which steam engines are used are ____.

Steam is generated from water by the heat energy released by the ____ of the fuel under the ____. The steam first enters the engine in the ____, which is marked by the letter ____ in the diagram. The ____ moves back and forth in the cylinder, being pushed by the ____ of the steam. Steam gets into the cylinder through openings marked ____ and ____ in the diagram. When one of them is admitting steam to the cylinder the other is connected with the ____, allowing the used steam to ____. The opening and closing of these ports or openings into the cylinder is controlled by the ____ valve marked ____ in the diagram. The flywheel is shown at ____ in the illustration.

Experiment 115. How is the energy of gas and oil harnessed?

Secure a can of about a gallon capacity, with a tight fitting lid. A smaller size will work. Make a hole in the side and insert an old spark plug taken from an automobile. Secure a spark coil and connect it with three dry cells and a switch, as shown in the illustration. Attach the high tension or secondary wires as shown in the illustration, one to

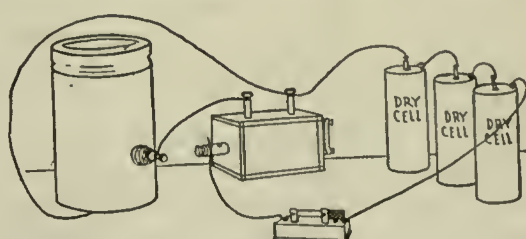


FIG. 269

[1] See workbook, p. 59.

the spark plug and the other so that it touches some part of the can. Now spray a little gasoline into the can with an atomizer or Flit spray. Place the lid on securely and close the switch. Stand away from the can and be cautious as the switch is closed. In your notebook record the notes of this experiment. Write a summary paragraph explaining your results and pointing out how this set-up is modified in the gasoline engine.

Experiment 116. How can the horse power of one's body be determined?

The horse power is a unit for measuring the rate at which a machine can do work. One horse power is work done at the rate of 33,000 foot pounds per minute or 550 foot pounds per second. Locate a straight flight of stairs from ten to fifteen feet high. Measure the height of one step in feet and multiply this by the number of steps. This will give the exact height of the stairs. Determine the time in seconds that it takes you to run to the top. Your weight multiplied by the height of the stairs in feet will give the foot pounds of work done. Divide this by the number of seconds it takes you to reach the top and it will give the number of foot pounds of work done per second. If this is again divided by 550 it will give the horse power of your body. Try several times and record your data in your notebook.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How is the energy of coal harnessed and controlled? Our homes are heated and lighted by energy which comes from coal, oil, gas, or water power. Automobiles, airplanes, locomotives, and ships are all driven by energy derived from coal or oil. Rapid communication is made possible only by electricity, which may also come from any of the natural sources named above. Industry would not long continue if our natural supplies of energy were suddenly cut off. Think what a calamity would result. Man has harnessed the power of most of the natural sources of energy including coal, oil, gas, water power, wind power, and to a small extent the power of the tides. Recently Claude, a French scientist, attempted to harness the heat energy of warm ocean waters, but found the process too difficult for general use.

FIG. 270. HERO'S BALL OF THE WINDS

As long ago as 130 B.C. man began experimenting with the power of steam. About that time a man by the name of Hero, who lived in the city of Alexandria, Egypt, made what he called a "ball of the winds." He had a globe with a pair of hollow bent arms extending from it in opposite directions as shown in Figure 270. The globe was partly filled with water and a fire built under it. As steam issued from the bent arms and pushed against the air, the globe turned much as a whirling lawn sprinkler turns when water pushes against the air as it comes out of the tiny openings. The ball of the winds was only a toy, but it was the probable beginning of our modern steam turbine.

In 1601 Porta, an Italian, built a type of engine in which he used the expansive power of steam to do work. Steam was generated from water in a boiler and forced to the top of a second chamber partly filled with water. Another pipe led from the water chamber to a higher level. As the steam expanded it pushed on the surface of the water with sufficient force to raise some of it to a higher level. Figure 271 shows how Porta's original engine appeared. In 1629 another Italian by the name of Branca built an engine run by steam which in some ways closely resembles a modern steam turbine. A jet of steam was blown against the blades of a specially constructed wheel, causing it to turn. It is said that this engine was used by Branca for pounding drugs and other chemicals. Figure 272 is a drawing of Branca's engine.

FIG. 271. PORTA'S ENGINE

One of the greatest steps forward in harnessing the energy of coal by means of the steam engine came in the discovery of the cylinder and piston by Denis Papin, a Frenchman. The piston moves inside the cylinder as shown in Figure 277. The piston is used in modern steam, gas, and oil engines.

The first steam engine to make use of the piston was built in 1705 by an Englishman named Newcomen. In reality it was not a steam engine (in the modern sense), but an air pressure engine. A study of Figure 273 will show that Newcomen's engine operated a lever beam, to one side of which was attached a heavy counter balance weight. Steam from the boiler was first admitted to the cylinder and then cut off by closing a valve. Cold water was then sprayed into the cylinder. This condensed the steam and decreased the pressure inside the cylinder. The greater air pressure on the outside then pushed the piston down,

FIG. 272. BRANCA'S ENGINE

raising the other side of the beam and making it possible to do work. As more steam was let into the cylinder, the counter balance weight helped raise the piston and lower the other end of the beam.

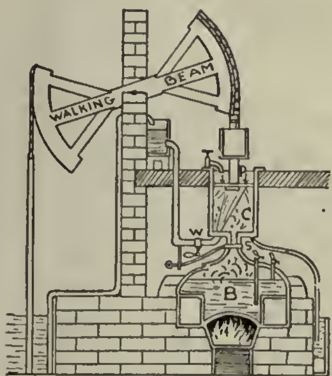
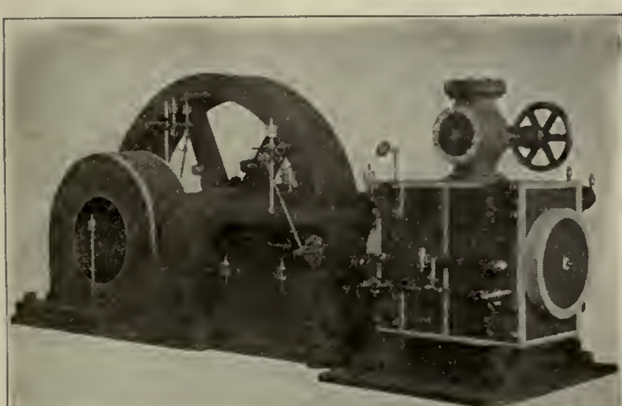


FIG. 273. NEWCOMEN'S ENGINE

To James Watt we owe the development of the modern steam engine. In 1763 he was working as an instrument maker at the University of Glasgow in Scotland. A model of Newcomen's engine was brought to him for repair and he became greatly interested in it. He was quick to see that a large amount of heat energy was lost each time the cylinder walls had to be warmed by the new steam which was admitted. Watt suggested that it would be more efficient if the cylinder were also closed at the other end and if steam instead of air pressure were made to push the piston to and fro in the cylinder. In Watt's engine, by means of a slide



Courtesy Hoover, Owens, Rentschler
FIG. 274. A MODERN STEAM ENGINE

valve, the steam is admitted first to one side of the piston and then to the other. This keeps the cylinder always hot and thus saves much heat energy formerly wasted in the Newcomen engine. If you do not now understand how the modern steam engine works, turn to page 163 and review the experiment. While Watt greatly improved the steam engine, he realized that not all of the heat energy of the steam was being used. Much of it escaped with the exhaust steam which was still very warm. Modern steam engines, called compound engines, are now used and get more useful work out of the steam and thus are more efficient. Figure 274 is a picture of a modern steam engine.

Modern steam turbines differ from the one made

Courtesy General Electric Company
FIG. 275. ROTOR

by Branca in 1629 chiefly in their efficiency; that is, in getting more useful work out of the heat energy of the steam. The basic principle is still causing a jet of steam to push against a wheel (Fig. 276). Figure 275 shows one of these rotors, as they are called. Some modern steam turbines make the steam run past several rotors until most of its push has been used.

How is the energy of gas and oil made available? Crude oil, or petroleum, is found in many parts of the United States and in other countries. The crude oil is used in some places as a fuel, but finds its energy in the form of gasoline for automobiles, airplanes, and tractors. From crude oil, by various refining processes, man gets naphtha, benzine, kerosene, gasoline and vase-

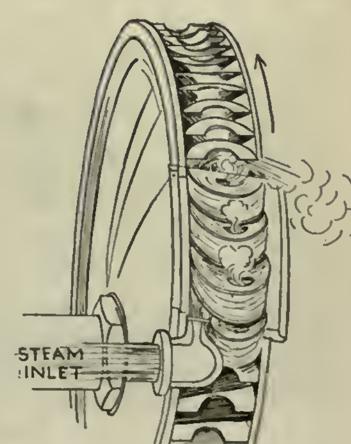
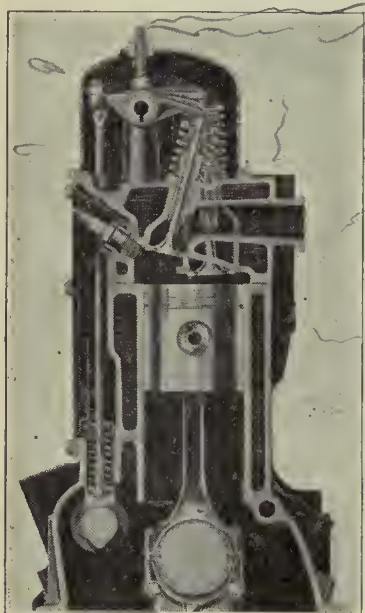


FIG. 276. STEAM PUSHING ON TURBINE ROTOR

line. Of these, gasoline is most important because of its use as gas engine fuel.

Gasoline is a fuel which is easily vaporized. This vapor, when mixed with the proper amount of air, forms a very explosive mixture. The gasoline engine draws such a mixture of gasoline vapor and air into its cylinders and explodes it with an electric spark. The force of the exploding gas pushes a piston down with great force, thus harnessing the energy of the gasoline. Figure 277 shows a cross section of one cylinder of a gasoline engine. Another type of oil engine called the Diesel engine after its inventor, Rudolph Diesel, is being used on some types of ships and for turning electric generators. Recently these engines have been used in an experimental way in airplanes and automobiles. The chief advantage of the Diesel engine over the gasoline engine is in the fact that it can run on a cheaper fuel. It can, in fact, be run on crude oil. The Diesel engine does not require an electric spark to explode the fuel, which is sprayed into its cylinder. Air is first drawn into the cylinder and then compressed under a very high pressure. This heats the air to such a high temperature that when the fuel is sprayed in, it immediately explodes. Because of the high pressure the cylinder walls of the Diesel engine must be thick and strong. This makes a very heavy power unit and has prevented its adoption for automobiles and airplanes. The picture in Figure 278 shows a modern Diesel engine.

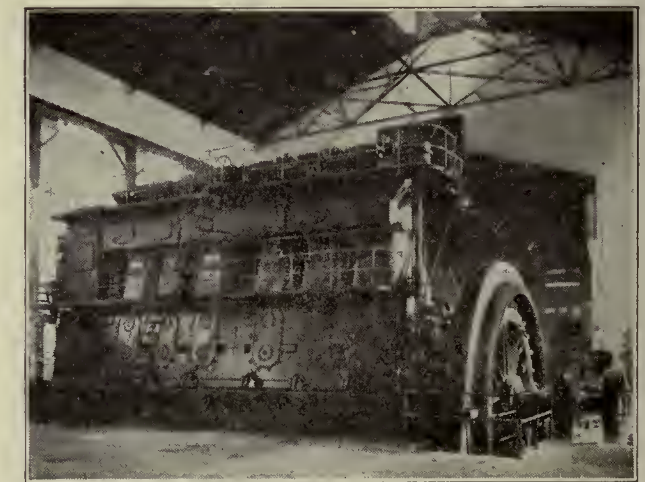


Courtesy General Motors

FIG. 277. MODEL OF A GAS ENGINE CYLINDER

How is the energy of falling water harnessed? For centuries man has used falling water as a source of energy. Sawmills, grist mills, and other larger industries were run by great wheels turned by the water as it rushed past on its way to the ocean. Today water power finds its chief use in generating electrical energy which can be sent long distances over wires with only a small loss.

There are four types of water wheels. In the overshot wheel the water runs over the wheel and turns it by the weight of the water as it falls. This type of wheel is used in hilly country where there is a considerable fall but a comparatively small amount of water. Its efficiency varies from 75 per cent to 85 per cent.



Courtesy Busch-Sulzer Bros.

FIG. 278. A MODERN DIESEL ENGINE

The undershot water wheel is used when there is a large volume of water with only a little fall. This type of wheel is about twenty-five per cent efficient. These wheels, extensively used in the past, have gradually given way to two other modern types. The Pelton wheel is a modification of the undershot wheel

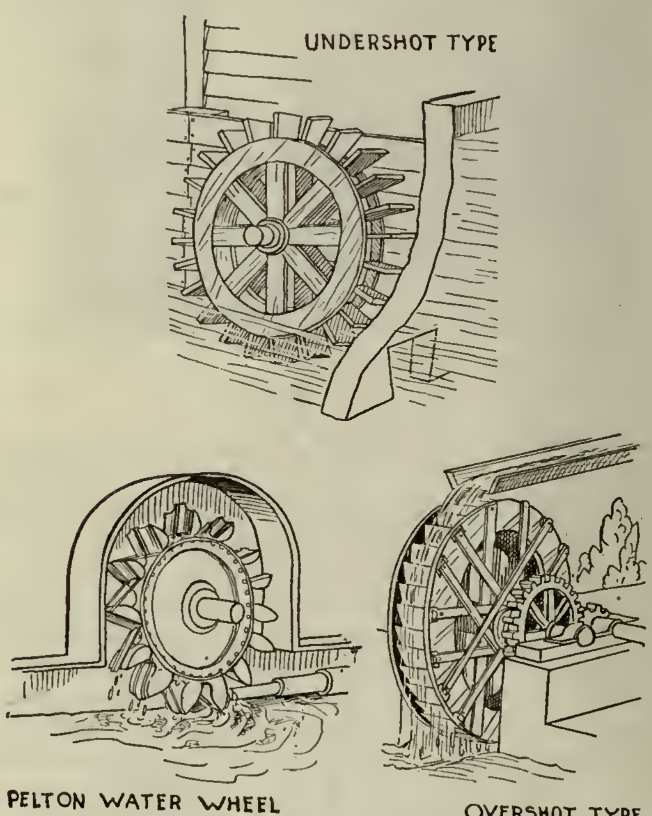


FIG. 279. TYPES OF WATER WHEELS

in which the water is shot through a nozzle against the under blades of the wheel. In this way the efficiency is raised to about 75 per cent. Figure 279 shows the construction of the three types of wheels.

The development of hydroelectric power in the United States has also brought about the development of a more efficient device for securing the greatest amount of energy possible from the falling water. This device is known as the *water turbine*. The water is taken from a dam or large waterfall and run through a closed pipe or duct to the turbine wheel and out through a tail race. The turbine wheel is usually set in a vertical position and connected directly to the electrical generator. Such turbines have efficiencies as high as 90 per cent. Figure 280 shows a cross-section diagram through a modern hydroelectric power plant. Great quantities of energy are being wasted yearly in unharnessed water power. The following table shows the estimated available water power of the world and the amount developed. The amounts are expressed in horse power. This is a unit of working rate. When a source of energy is doing work at the rate of 33,000 foot pounds per minute it is working at the rate of one horse power.

COUNTRY	AVAILABLE H.P.	DEVELOPED H.P.	PER CENT DEVELOPED
United States ..	35,000,000	13,500,000	38.6
Canada	19,000,000	5,100,000	26.9
Mexico	6,000,000	300,000	5.0
Remainder of North America	6,000,000	260,000	4.35
South America..	54,000,000	800,000	1.5
Europe	57,000,000	14,000,000	24.6
Asia	69,000,000	2,100,000	4.0
Africa	190,000,000	14,000	0.007
Oceania	17,000,000	250,000	1.5
World Total..	453,000,000	36,324,000	8.02

Each year finds new water power projects in progress, thus lessening the great energy losses. The Hoover Dam project in the United States and the Dnieper River project in Russia are two of the largest ever attempted. Figure 281 shows a picture of a water power project in the Ozark Mountains of Missouri. The Osage River has been held back by a huge dam, creating a lake with an area of 95 square miles and a shore line of 1,300 miles. The water enters the penstocks[1] through huge gates which are opened and closed by the cranes traveling along the top of the dam. This project alone, when completed, will harness more than 128,000 horse power of previously wasted energy.

[1] *Penstocks*, gates or passageways for regulating the flow of water.

What is the source of the energy about us? It seems strange to think that the light energy from an electric bulb came from the sun, but a little thought will show that this is true. The light energy came from electrical energy which was produced from the mechanical energy of a steam engine, steam turbine, or waterfall. In the steam turbine and engine, heat energy from coal was used to furnish the mechanical energy. Where did the coal get its energy? From the sunshine that fell millions of years ago on great tropical forests which were later changed into coal beds. If the electrical energy for the light came from a water power project the sun, of course, furnished the heat to evaporate the water; the vapor condensed, fell as rain, and finally rushed down the mountain toward the ocean. In this same way nearly all energy can be traced back to the sun as its source. Try to trace to its remotest source the energy you use in walking.

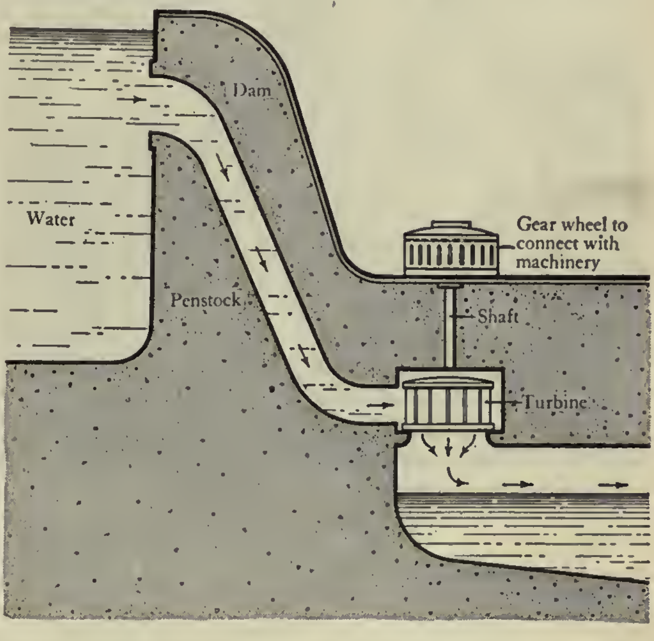
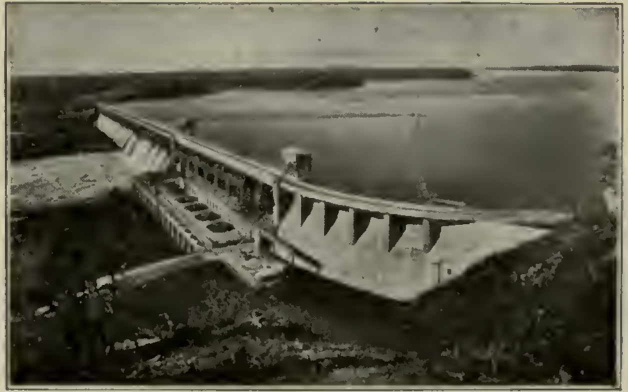


FIG. 280. CROSS SECTION OF A WATER-POWER SYSTEM

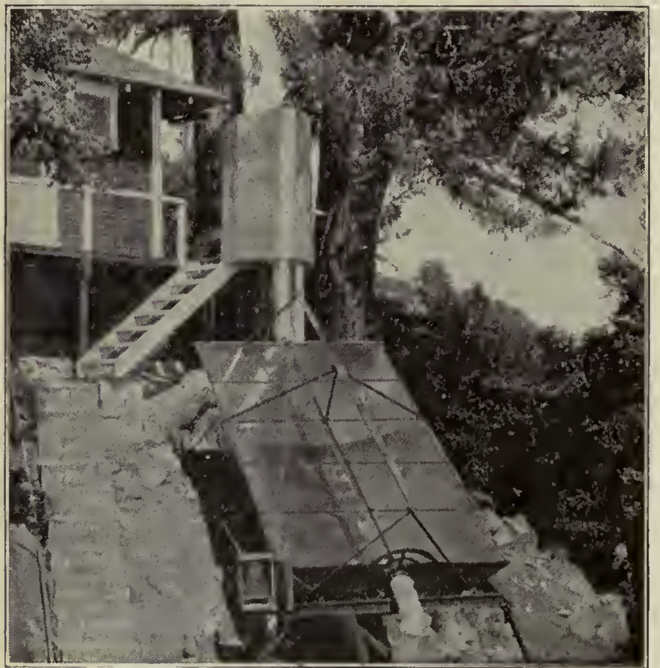


Courtesy Union Electric Light and Power Co.

FIG. 281. BAGNELL DAM ON THE OSAGE RIVER IN MISSOURI

Can you trace the mechanical energy of the automobile back to the sun?

In most instances the energy of the sun is utilized by man indirectly through coal, gas, or falling water.



Courtesy Smithsonian Institution

FIG. 282. SOLAR COOKER

However, there have been several attempts to harness the sun's energy directly, and some of these have been moderately successful. In Florida and California many persons have installed water coils which supply their homes with water heated by the sun's energy.

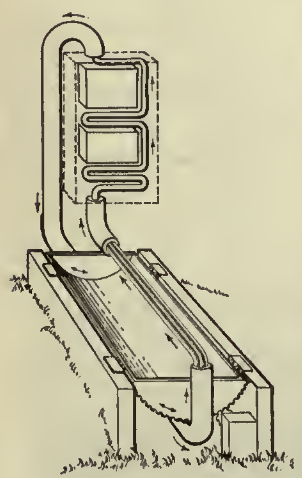


FIG. 283. DIAGRAM OF SOLAR COOKER

One of the simplest and most efficient devices ever designed to harness the energy of the sun directly is shown in Figure 282. It was built by Dr. C. G. Abbott, director of the Smithsonian Institution. A cylindrical mirror made from sheet aluminum collects the heat rays from the sun and focuses them on a small tube in the center. This tube contains some liquid such as oil or water and is connected to a system of tubes through which the liquid may circulate as it becomes heated. The construction of the tube is interesting. A blackened copper tube is placed inside two glass tubes. The oil circulates inside the copper tube. The photograph shows how Dr. Abbott has used this solar heater for purposes of cooking. The drawing is a detail of the working parts.

Exercise. *Study the drawing of Figure 283 carefully and note all the ways taken to get the greatest amount of heat energy to the oven. Tell what scientific principle is made use of in each of the attempts to increase the efficiency of the cooker.*

There are at least five types of energy: heat, light, electrical, mechanical, and chemical. Some scientists believe that matter itself is a sixth type. Many of the common devices which we use every day are energy transformers—electric lights, heaters, and motors; coal and gas stoves; dry cells and storage batteries. In every case of transformation, some energy is wasted, for there are no devices which are one hundred per cent efficient. Can you name other devices which we use to transform one type of energy into another?

REFERENCES FOR FURTHER STUDY

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Bond, *With the Men Who Do Things*

Burns, *The Story of Great Inventions*

Darrow, *Masters of Science and Invention*

Marshall, *The Story of Human Progress*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of how the sun is the source of all energy and the ability to trace all energy back to it.
2. An understanding of the law that energy can neither be made nor be destroyed by man, but can be changed from one of its forms into another.
3. An understanding of the way in which the following things work: electric heating devices, steam engines and turbines, electric lights and gas lights, water wheels and turbines, electric motors and generators.

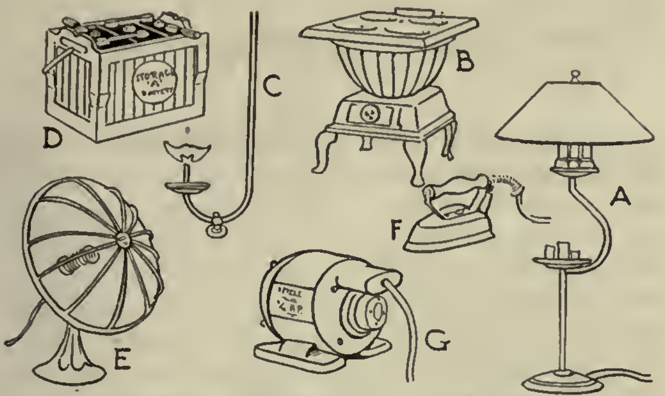


FIG. 284. COMMON ENERGY TRANSFORMERS

4. Something of the world's supplies of natural energy, such as running water, coal, oil.
5. An intelligent attitude regarding our obligation to conserve and use carefully the present supplies of natural energy.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Name the four types of water wheel.
2. Show how the light and heat energy of an electric-light bulb came originally from the sun.
3. What devices are used by man to change electrical energy into light and heat energy?
4. How do coal and oil possess energy?
5. Chemical energy is changed into electrical energy in the ____ battery and the ____ battery.
6. Figure 284 shows several devices which bring about energy changes. Each device is designated by a letter. Write the letters, and after each letter write the kind of energy change represented by that device.
7. Name four types of energy change.
8. What happens to energy which has been used?
9. Name at least seven sources of natural energy.
10. Complete the following statement as a general concept which you have gained from the study of this topic.

All energy comes from the ____. It is transformed by man through such devices as ____.

SUPPLEMENTARY MATERIALS

Reading suggestions

Burns, *The Story of Great Inventions* (Harper)
Bond, *On the Battle Front of Engineering* (Century)
Collins, *The Amateur Mechanic* (Appleton)
Gibson, *The Romance of Scientific Discovery* (Lippincott)
Parkman, *Conquests of Invention* (Century)
Collins, *The Boy's Book of Experiments* (Crowell)
Williams, *How it Works* (Nelson)
Quennell, M. and C. H. B., *Everyday Life in the New Stone, Bronze, and Early Iron Ages* (Putnam)
Holland, *Historic Inventions* (Macrae-Smith)
Iles, *Leading American Inventors* (Holt)
Williams, *The Romance of Modern Engineering* (Lippincott)
Bock, *What Makes the Wheels Go 'Round* (Macmillan)
Darrow, *The Boys' Own Book of Great Inventions* (Macmillan)
Collins, *Experimental Mechanics* (Appleton)
Andrade, *Engines* (Harcourt)
Hawks, *The Boys' Book of Remarkable Machinery* (Dodd)
Wilkins, *Marvels of Modern Mechanics* (Dutton)
Pupin, *Romance of the Machine* (Scribner)
General Motors Co., Research Division, *When the Wheels Revolve; Diesel, the Modern Power; Chemistry and Wheels*

Reports which may be prepared

1. The early history of the lever
2. Building of the pyramids
3. The use of machines on the farm
4. The use of machines in the home
5. Machines in building skyscrapers
6. The invention of the sewing machine
7. McCormick and the reaper
8. Harnessing Niagara Falls
9. The development of water power
10. Future sources of energy
11. Harnessing the energy of the tides
12. Harnessing the energy of wind
13. The construction and uses of dams
14. Some fancies in perpetual motion
15. The story of weights and measures
16. The Diesel engine as a source of power for automobiles and airplanes
17. Centrifugal force and how we use it
18. Should we adopt the metric system?
19. The work of the Bureau of Standards

Great scientists you should know about

1. Archimedes
2. Lord Kelvin
3. James Watt
4. Sir Isaac Newton
5. Rudolph Diesel

Investigations and things to do

1. Make a set of levers of the various classes.
2. Make model water wheels of the various types.
3. Measure the efficiency of a jack screw.
4. Construct a wheel and axle and measure its efficiency.
5. Determine the horse power of your body.
6. Study the construction of a reaper and binder.
7. Study the construction of a sewing machine.
8. Study the construction of a typewriter.
9. Make a scrapbook of magazine and newspaper clippings related to the materials of this unit.

UNIT VIII. THE RELATION OF OUR EARTH TO OTHER HEAVENLY BODIES

The heavenly bodies have always been a source of wonder to mankind. Early man observed the heavens because he needed to know about them in order to survive. The position of the sun in the heavens served as his clock during the day, and the light from the moon and stars guided him at night. Eclipses, comets, and meteors were to primitive man evil signs of the wrath of a displeased god. Even today there are ignorant people who live in fear of such beautiful phenomena in the heavens as comets and eclipses.

As man became more civilized, he slowly accumulated knowledge of the heavenly bodies and organized it into a crude form of science called *astrology*. Astrology, which consisted of a body of facts mixed with much superstition and fancy, flourished in Babylon as early as 3000 B.C. and spread from there to other regions of the ancient world. Today astrology is no longer considered a science by intelligent people. There are persons among us, however, who call themselves astrologers. They claim that they are able, by observing the stars and planets, to foretell events and to give sound advice in love, marriage, and business. Most of these persons are frauds who are able to make a living because superstitious people believe what astrologers tell them.

Astronomy, the oldest of the sciences, had its beginnings in astrology. Astronomers, by years and years of patient observation, have accumulated a large body of knowledge of the heavenly bodies that enables us to cast aside all our fears of celestial phenomena. Today we look forward months and years in advance to the exact second when an eclipse of the sun or moon will occur. The mysteries of the comet and meteor have been solved, and we await with delight the return of a comet or the November meteors.

The ancients, working with the crudest of instruments and only with the naked eye, discovered many things about the heavenly bodies. Ptolemy, an Egyptian who lived in the second century A.D., explained the motions of the planets, but his explanations were based upon a solar system with the earth as the center. Centuries later Copernicus, a Polish astronomer, conceived the idea that the sun is the center of our solar system. In 1610 Galileo made the first telescope, and with it came the era of modern astronomy. Since then new and better telescopes and other marvelous astronomical instruments have been built, and new discoveries have followed rapidly.

We live on a tiny speck in space acording to the astronomers. Our sun is one of millions of stars and a relatively small and unimportant one at that. Astronomers believe that the universe of which our solar system is a part is shaped like a watch and that it is only one of many such universes which fill space. These theories and facts about the heavens make a most fascinating study.

What do you know about the earth and other heavenly bodies? Write the answers in your notebook under the proper heading.

1. How many changes does the moon appear to make?
2. What causes an eclipse of the sun? Of the moon?
3. Who invented the telescope?
4. What kinds of heavenly bodies can you name?
5. What constellations do you know?
6. Why do we have summer and winter?
7. What is the evening star? The morning star?
8. What is the name of the latest discovered planet?
9. What is the difference between a star and a planet?
10. What is the Milky Way?

TOPIC 1. LEARNING ABOUT THE STARS

SUGGESTED PROBLEMS AND QUESTIONS

1. How many stars can you see on a clear, moonless night?
2. What is a light year?
3. What is the nature of the Milky Way?
4. How large is our galaxy of stars?
5. How many constellations are there?
6. What is the nature of a star?
7. How are telescopes constructed?

SUGGESTIONS AND HELPS FOR STUDY

1. In learning the constellations you will find it helpful to have before you a map of the heavens for that particular month. In Figure 285 you will find maps showing the principal constellations in each month of the year. After locating the constellation on the star map, observe it in the heavens.

2. Search the references for all the material which you can find relative to planets, stars, and nebulae. Astronomers have discovered some fascinating things regarding them.

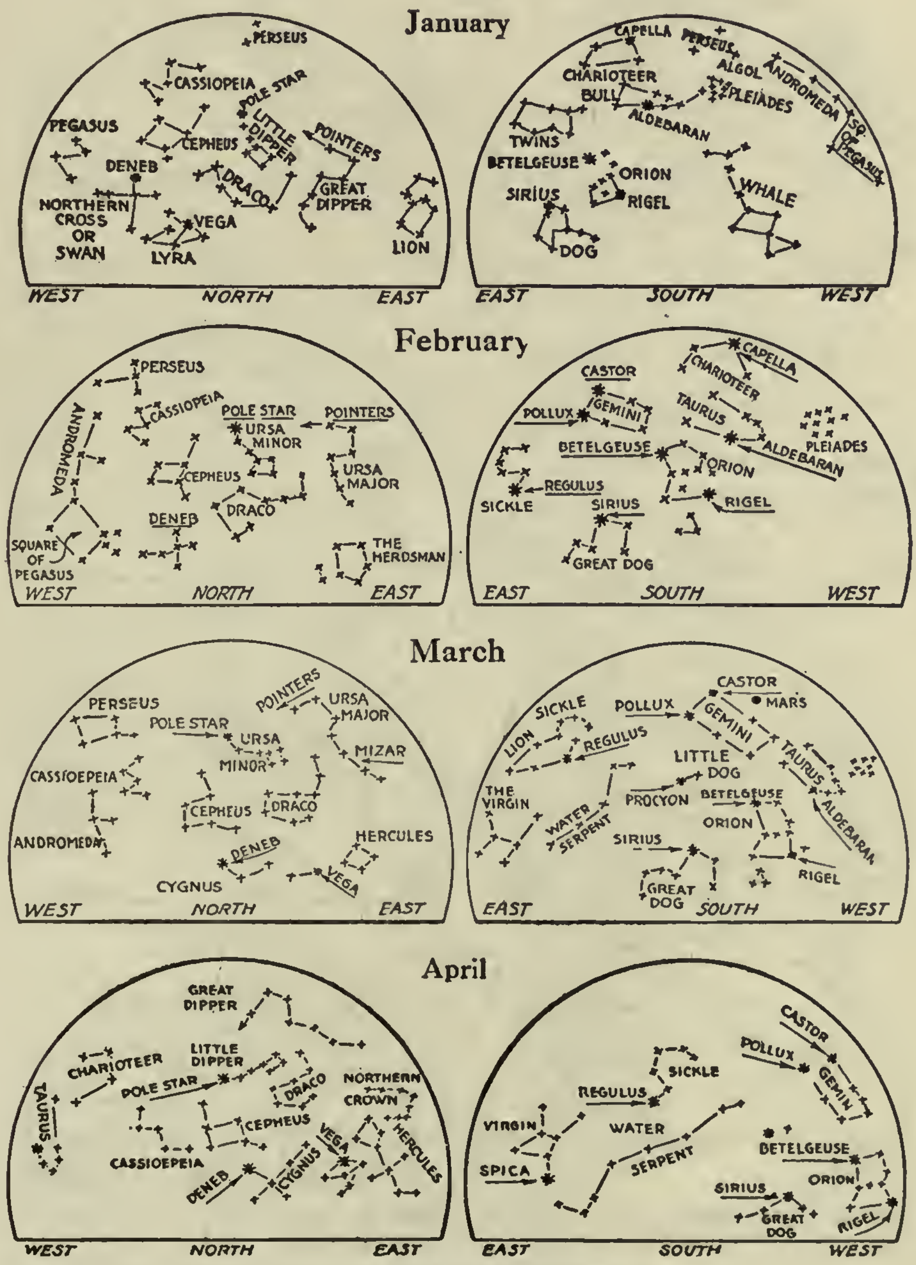
3. You should learn something about the tools which the astronomer uses. Do not try to learn all about the workings of these, as they are quite complicated, but know the chief differences of the two types of telescopes and for what the spectroscope is used. In connection with this problem you may wish to learn something of the great astronomical observatories of the world.

4. You may find the following new words and phrases in this study:

constellation—a group of stars, in whose peculiar shape the ancients saw some likeness to an animal or god or with which they associated some myth or legend.

luminous—giving off light.

refraction—the bending of light rays. The common bent appearance of a stick when placed in water is due to refraction.



From The Science Classroom. *Courtesy of Popular Science Publishing Co.*

FIG. 285A. STAR MAPS

galaxy—our system of stars in space, including the Milky Way.

meteor—commonly referred to as a "shooting star" but incorrectly. It is a piece of matter falling through space which is heated to glowing by the friction of the

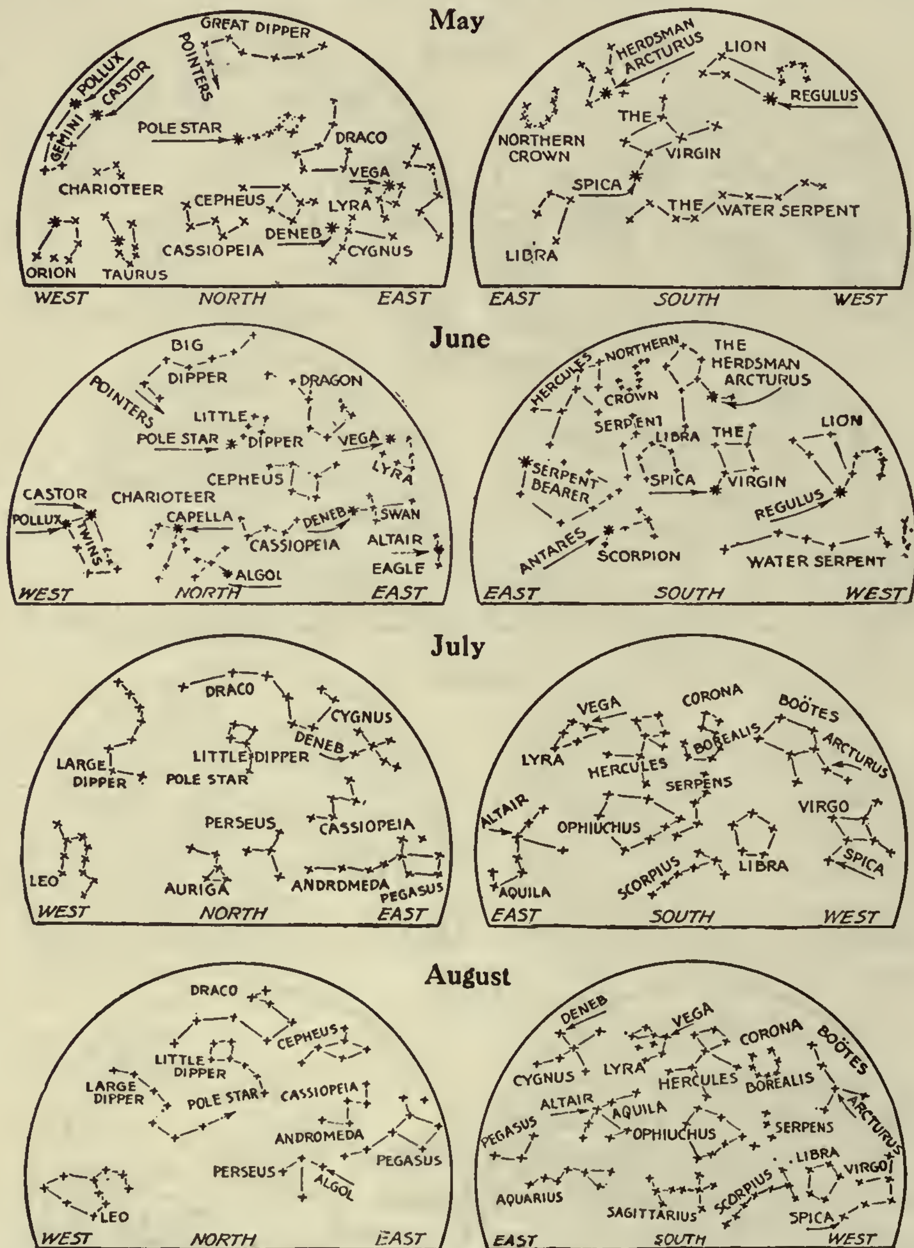
earth's atmosphere. These fragments are usually consumed by the heat.

nebula—a cloud-like object in the distant celestial spaces that glows from it own light.

satellite or moon—a body revolving about a planet.

one of the northern skies and the other of the southern skies.

Select the maps for the month in which you are observing and locate on the map the particular constellation which you wish to find in the heavens. Get an idea of the general position of the constellation, that is, its distance above the horizon and its location to the east or west of a line drawn from the top of the star map to the bottom. Also get in your mind as clear a picture as you can of the shape of the constellation. If the star group is found on the map of the northern skies, face north, and if on the other map, face south. If possible, have your star map before you and illuminate it with a flashlight from time to time to check your observations.



From The Science Classroom. *Courtesy of Popular Science Publishing Co.*

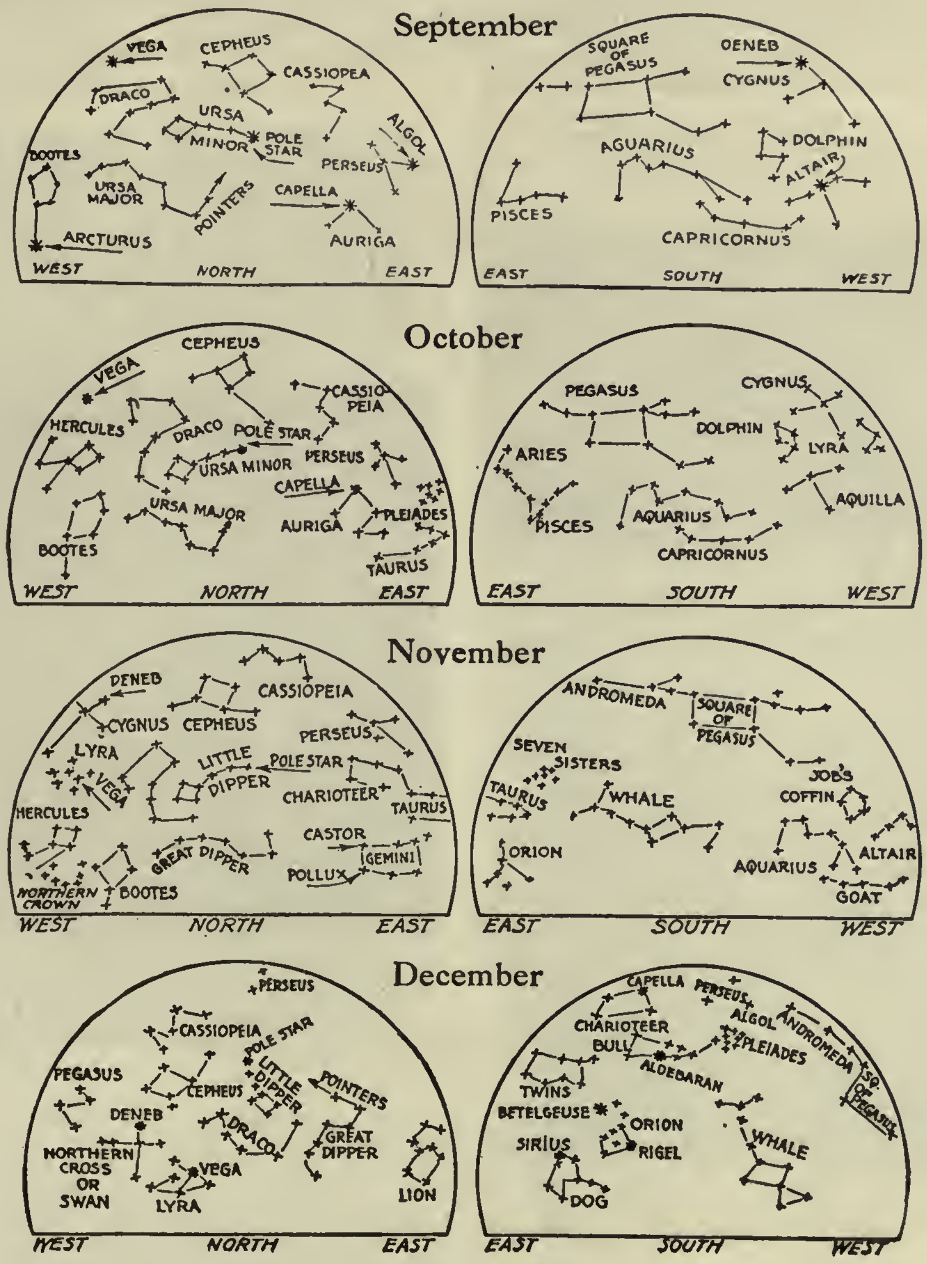
FIG. 285B. STAR MAPS

INVESTIGATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Activity 117. How are the star maps used in locating the constellations?

Each star map in Figure 285 is drawn to represent the heavens for a given month of the year. Examine these maps and observe that there are two diagrams for each month,

Do not be discouraged if you have some difficulty in locating the constellation, for you may be confused by the many stars in the heavens that are not shown on the map. Also the stars of your constellation may not all be sufficiently bright to be readily seen. This is the case of many of the stars of the Little Dipper (Ursa Minor), especially when observed from a city where the lights make observation difficult.



From The Science Classroom. *Courtesy of Popular Science Publishing Co.*

FIG. 285C. STAR MAPS

Choose a constellation from the following list, all of which occur in the northern skies, and try to locate it by using the star maps of the month in which you are observing and by following the suggestions given in the preceding paragraphs.

The Great Dipper (Ursa Major)
The Dragon (Draco)
The Queen's Chair (Cassiopeia)
The Little Dipper (Ursa Minor)
The King (Cepheus)

In your notebook[1] complete the following statements and sketch the shape of the constellations observed.

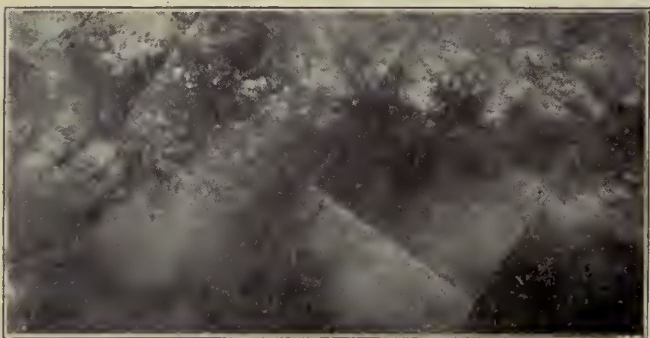
The constellation which I observed is called ____ or ____. It is located in the ____ heavens. I first observed it on the star map for the month of ____ and found that it is located in the ____ part of the ____ skies. The shape of the constellation shown in the sketch in my notes is as I observed it. I made my observation about ____ o'clock in the evening.

[1] See workbook, p. 65.

Activity 118. How can the North Star (Polaris) and some of the common northern star groups be located from the Great Dipper?

Select the star map of the northern skies for the month in which you are observing. Locate the Great Dipper (Ursa Major) and then locate it in the evening skies by observation. Find the two stars in the bowl of the dipper on the side away from the handle and carefully observe the distance between them.

On your star map imagine a line drawn through these two stars and follow it in the direction of the upper one a distance equal to about five times the distance between them. You should arrive at the last star in the handle of the Little Dipper. This is Polaris, the North Star. When you have located it on the star map, make the observation in the evening skies. You may have to look sharply to see Polaris, as it is not an extremely bright star.



Courtesy Mount Wilson Observotory

FIG. 286. THE MILKY WAY

Note that the illustration is made of a number of photographs pieced together.

The Little Dipper can be located from Polaris. Notice that the bowl of the Little Dipper seems always to be pouring into the bowl of the Great Dipper.

Cassiopeia, the Queen's Chair, can be located from the Great Dipper by passing a line from a point in the middle of its handle through the Pole Star and continuing as far on the other side as Polaris is from the Great Dipper. Observe this on the map and then in the evening skies.

Draco, the Dragon, always curls its tail down between the two Dippers. Locate it in this way on the star map and then find it in the evening sky.

In your notebook write a summary paragraph telling of your experiences in making the observations required in this investigation.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. How can one make a star finder? See *American Boy's Engineering Book* by Bond or *The Book of Stars* by Collins.
2. How can a planisphere be made? See *Our Physical World* by Downing.
3. How may the heavenly bodies be photographed? See *The Book of Stars* by Collins.
4. How may a simple telescope be made? See *The Book of Stars* by Collins or *The Boys' Own Books of Great Inventions* by Darrow.
5. How may a reflecting telescope be made? See *Amateur Telescope Making*, edited by Ingalls.

NOTE: This is a painstaking exercise and should be undertaken only by a group that is willing to put in long hours of careful and difficult work. It is, however, a project which, once completed, will yield many hours of fruitful returns.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How many stars can you see on a clear, moonless night? Have you ever gone out under the open sky, on a clear and moonless night, and tried to count the stars? If you have, no doubt you found the task a difficult one. The stars seem scattered like tiny points of light in great profusion over the heavens. Their number seems countless. But one of the first things everyone must learn when he begins a study of the heavens is that things are not always as they seem. The stars visible to the naked eye from the north pole to the south pole have been counted, and the number is approximately 6,000. But since only half this number is above the horizon at any moment and since the haze in the atmosphere near the horizon prevents faint stars there from being seen, only about 2,000 stars are visible at one time. Of course there are many more than 6,000 stars. Through an opera glass at least 100,000 stars can be seen, and our largest telescopes show millions of them.

Courtesy Mount Wilson Observatory

FIG. 287. SPIRAL NEBULA VIEWED EDGEWISE

Notice that it is shaped much like a watch. Our galaxy is somewhat similar in shape.

Neither are the stars the tiny, twinkling points of light they seem to be. They seem so only because of their great distances from the earth. With the exception of our sun, the nearest star (Alpha Centauri)

is 25,000,000,000,000 miles away, and about four and one-third years is required for its light to reach us. We know that the stars are gigantic self-luminous masses of glowing solids, liquids, or gases. Many of them are larger than our sun, which has a diameter of 865,000 miles, but because of their great distances from us they appear like sparkling jewels studded in the sky.

Courtesy Bausch and Lamb Optical Company

FIG. 288. GREAT HERCULES STAR CLUSTER

There are other bodies than stars in the heavens. *Planets* are much smaller bodies that revolve around a sun. Some of them look larger and brighter than stars because they are much nearer to us. They are not self-luminous but shine by reflected light from the sun. You can distinguish a planet from the stars because it gives off a steady light, whereas stars twinkle. Also, planets change their position among the stars. Are you acquainted with the planet Venus, sometimes known as the morning or evening "star"? The moon, meteors, and comets are still other heavenly bodies that attract our attention, but they will be described later.

What is a light year? In our study of the heavens we must become accustomed to thinking of great distances. Our unit of measurement of long distances on the earth is the mile. Star distances are not generally given in miles because the figures are so large that they cease to have any meaning to our minds. Instead, the distance light travels in a year is taken as the unit. Light travels about 186,000 miles a second or about 6,000,000,000,000 (six trillion) miles a year. The distance that light travels in one year is the unit of measurement of distance in astronomy, and it is called the *light year.* The distance to our nearest star except the sun is about four light years. The North Star is forty light years away, and there is evidence that some of the most distant stars are at least 1,000,000 light years away.

Caurtesy Mount Wilson Observatary

FIG. 289. A SPIRAL NEBULA, FULL VIEW

What is the nature of the Milky Way? Have you ever seen the Milky Way, that faintly glowing cloud of matter that stretches across the heavens? To the naked eye it has a milky appearance because of the apparent nearness of the stars to each other, but when looked at through a telescope it becomes a huge group of millions of stars (see Fig. 286). While the stars that make up the Milky Way seem very close to each other, they are in reality separated from each other by millions of miles.

How large is our galaxy of stars? The earth on which you live is only a tiny body among billions of heavenly bodies. As you look at the sky on a clear, dark night, space seems endless. However, the billions of stars visible through our modern telescopes do not extend to infinite distances. These stars are a part of a large group of stars that make up our *galaxy*. The Milky Way is a part of our galaxy. There may be more than 10,000,000,000 stars in our galaxy, though the

FIG. 290. NORTHERN CONSTELLATIONS

total number is as yet uncertain. Our galaxy occupies a disk-like or watch-shaped region whose thickness through its shortest diameter is estimated to be 5,000 light years, and whose long diameter is about 200,000 light years. Our sun with its family of planets is deep in the interior, not far from the center of our galaxy.

Outside our galaxy are globular clusters of thousands of stars. Most of them, because of their great distances from us, cannot be seen by the unaided eye. Even the Great Hercules cluster (see Fig. 288), one of the nearest and largest of the star clusters, appears without the aid of a telescope to be only a faint star.

Beyond our galaxy and the globular star clusters modern telescopes have disclosed countless other galaxies similar in many respects to our own galaxy. They are spread out in thin disks and contain hundreds of millions of suns. These galaxies, when observed with powerful telescopes, appear as great whirling masses called *spiral nebulae* (see Fig. 289). You will need to ponder these statements a long while to gain an appreciation of the vastness of space.

How many constellations are there? When we observe the night sky we notice that the brighter stars can be divided into groups which help us to locate and identify individual stars. Thousands of years ago the people of Persia, Egypt, Greece, and Rome noticed this, too, and they associated various groups of stars with animals, heroes, and even their gods. The names given centuries ago to these star groups or *constellations* are still used.

At the present time ninety constellations are recognized. Some of these are in the southern heavens, and cannot be seen by people in the United States because they are below the horizon. Most people find it interesting to identify constellations and to learn the names of the brightest stars. Star maps with directions telling how to use them are given with the laboratory problems at the beginning of this topic. See how many constellations you can become acquainted with before the end of your course in general

Courtesy Bausch and Lomb Optical Company

FIG. 291. GALILEO'S TELESCOPE

science. If you are a Boy Scout or a Girl Scout, why not obtain the Scout booklet on astronomy and see what you must learn about the heavenly bodies in order to pass the various tests?

Exercise. *Suggest the reason why the constellations around Polaris, the North Star, never set in the Northern Hemisphere but are always above the northern horizon.*

Exercise. *Carefully study the star diagrams, Figure 285. Observe the position of the constellation Ursa Major, the Great Bear, from month to month through-*

out the year. Infer a cause for the change you note in its position.

Exercise. *A person familiar with the stars can tell the hour of the night by observing the position of Ursa Major. Can you tell why this is possible?*

What is the nature of a star? Stars are intensely hot, self-luminous bodies that give off enormous quantities of energy. By means of an instrument called the *spectroscope*, astronomers analyze light waves that stars send out and in this way determine their chemical constitution. Stars are composed of iron, carbon, hydrogen, sodium, and other chemical elements of which the earth is made. In fact, all heavenly bodies are built up from the same substances. This is one of the great scientific discoveries of the past century, and it shows a wonderful unity in the universe.

Stars vary in their color. Stars that give off a bluish white light are young stars made up of intensely heated gases. As they become older they lose heat and change in color from white to yellow and eventually to a deep red. When they become very, very old they change to a solid state and give out no light. Not all stars, however, exhibit such a regular life history. Stars whose brightness changes irregularly are called *variable stars*. Occasionally a new star blazes out where none had been seen before. About forty stars of this class have been observed since 1572, most of them during the past century. Most of these temporary stars soon lose their brightness.

The stars are often called "fixed stars" because they seem to maintain the same relative positions to one another. They are, however, moving rapidly among themselves. The relative motion of the stars with respect to one another is about 600,000,000 miles a year, but because of their enormous distances from us the distances they move during a lifetime are not perceptible to us. Even the Egyptians during the time they were building the pyramids saw the constellations almost exactly as they are seen today. If, however, we could live on the earth 100,000 years from now, we should find the stars of the constellations in different positions with relation to each other.

How are telescopes constructed? The ancients were greatly limited in their observations of the heavenly bodies because they had only their eyes to collect starlight. About 1610 Galileo made a telescope which enabled him to see thousands of stars never before seen by man. Galileo's telescope revolutionized thought. He not only saw many new stars but he also saw the planet Jupiter with four satellites revolving around it. This gave strong support to the Copernican view that the sun is the center of our solar system and that the planets and satellites revolve around it. This discovery marked the downfall of the ancient notion that the earth is the center of our universe and established the study of the heavens on a firm foundation.

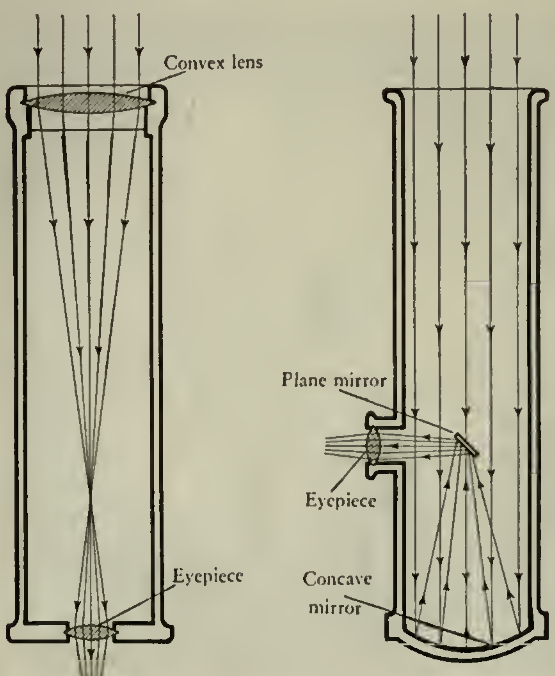
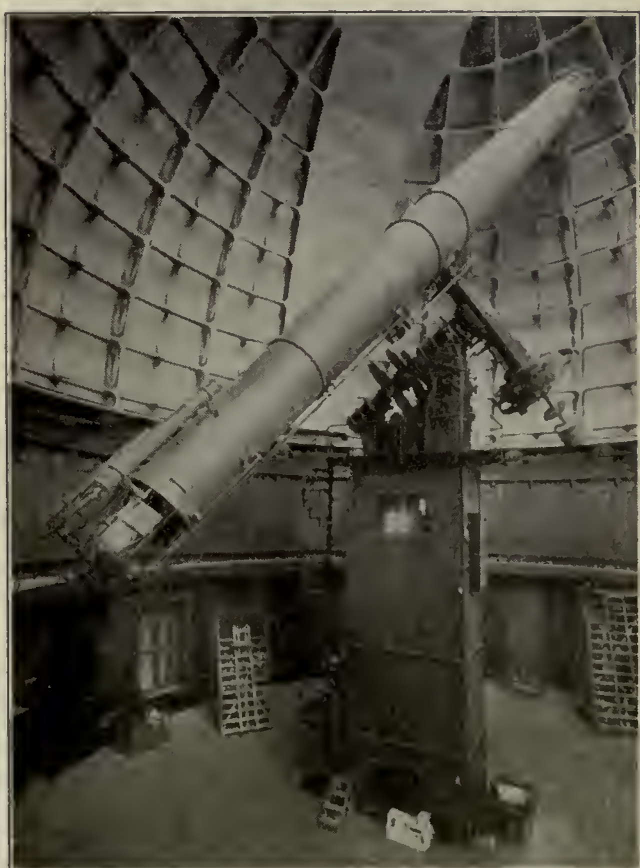


FIG 292. PRINCIPLE OF REFLECTING AND REFRACTING TELESCOPES



Courtesy Lick Observatory

FIG. 293. THE LICK 36-INCH REFRACTING TELESCOPE

Many years elapsed, however, before the true possibilities of the telescope were perceived. Today two types of astronomical telescopes are in use: the *refractor* and the *reflector*. In the refracting telescope (see Fig. 292) a convex lens is mounted at the upper end of the tube which is pointed toward the heavenly body. The light, after passing through the lens, is brought

Courtesy Mount Wilson Observatory

FIG. 294. LARGE REFLECTING TELESCOPE AT MOUNT WILSON OBSERVATORY

to a point near the lower end of the tube and forms an image of the heavenly body. The image may be viewed through an eyepiece at the lower end of the tube or it may be photographed on a sensitive plate. One of the largest instruments of this type is the 36-inch refractor of the Lick Observatory.

Reflecting telescopes are constructed quite differently. In this type of instrument a concave mirror (see Fig. 292) is used in place of a lens to collect the light. The reflection occurs on the upper surface of the mirror, which is covered with a coat of pure silver. At the time this is written the largest instrument of this type is the 100-inch reflector of the Mount Wilson Observatory in California. However, a 200-inch reflector is in the process of construction. In modern astronomical observatories both refracting and reflecting telescopes are used, each for the purpose for which it is best adapted. Since it is much easier to make a mirror than a lens, it is a favorite exercise for amateur astronomers to make their own reflecting telescope. To grind and polish a mirror requires patience, care, and skill, but many good ones have thus been made.

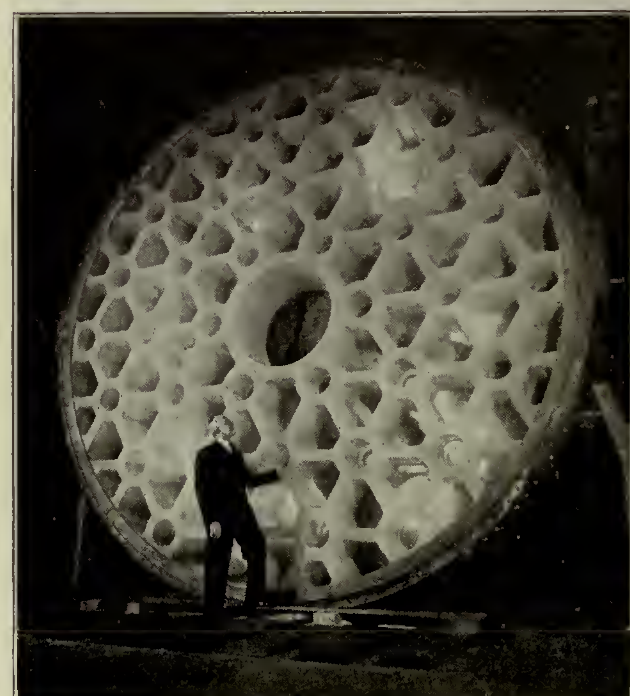
REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 15
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 11
Hunter and Whitman, *Science in Our World of Progress*, Unit 8
Lake, Harley, and Welton, *Exploring the World of Science*, Unit 5
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 1
Powers, Neuner, and Bruner, *This Changing World*, Chap. 1; *Man's Control of His Environment*, Chaps. 31 and 32
Skilling, *Tours through the World of Science*, Tour 6
Van Buskirk and Smith, *The Science of Everyday Life*, pp. 293-299
Watkins and Bedell, *General Science for Today*, Chap. 11
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 6
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It*, Topic 1

Special references

Collins, *The Book of Stars*
Martin, *The Friendly Stars*
McPherson, *The Romance of Modern Astronomy*
Ingalls, *Amateur Telescope Making*
Downing, *Our Physical World*
Bond, *The American Boys' Engineering Book*



Courtesy Corning Glass Works

FIG. 295. THE 200-INCH REFLECTOR

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of some of the more familiar constellations and the ability to recognize them in the heavens.
2. A knowledge of what the various heavenly bodies are and some of the things that science has learned concerning them.
3. Something of the tools used by the astronomer in his quest of knowledge about the universe.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Make a diagram showing the Great Dipper in its January position and the relative positions of Cassiopeia and Draco with respect to it.

2. Show by diagrams how the principal stars in the constellations Orion, the Pleiades, Lyra, Cygnus, and Gemini arrange themselves.

3. The spectroscope enables astronomers to analyze the ____ from stars and thus learn many things about them.

4. The astronomer's unit of measurement of distance is the ____.

5. A nebula is ____.

6. A planet is ____.

7. How does a refracting telescope differ from a reflecting telescope?

8. The nearest fixed star is ____ away.

9. Stars differ from planets in that ____.

10. What is the Milky Way?

11. Groups of stars that form conspicuous figures in the sky are called ____.

12. The speed of light is ____ a second.

13. The first telescope was invented by ____.

14. The North Star can be located by two stars in the ____.

15. List the names of constellations that you are able to identify in the sky.

TOPIC 2. THE SUN AND HIS FAMILY

SUGGESTED PROBLEMS AND QUESTIONS

1. **What heavenly bodies make up our solar system?**
2. **What is the nature of our sun?**
3. **What has science learned of the planets?**
   - **Distance from the sun**
   - **Size**
   - **Possibility of life**
   - **Type of surface**
   - **Length of day**
   - **Length of year**
4. **What are the characteristics of the other members of our solar system?**
   - **Asteroids**
   - **Comets**
   - **Meteors**
   - **Moons**

SUGGESTIONS AND HELPS FOR STUDY

1. Most of the material of this topic is informational in nature and will be found in the texts and special references.

2. Problem *2* offers some interesting points for investigation. How large is the sun? How far is it from the earth? What are sun spots? What is found in the sun? All of these questions and others should be answered by your reference study.

3. In connection with this study try to collect pictures of the planets, the moon, comets, etc.

4. Meteors occur in greatest numbers in August about the tenth of the month, in November about the middle of the month, and in December about the seventh of the month. Can you find the reason for this?

5. You may find the following new words and phrases in this study:

asteroids—relatively small pieces of matter which travel about the sun between the orbits of Mars and Jupiter.
orbit—the path of a heavenly body revolving around another body.
planetoid—an asteroid.
solar system—the sun and the bodies which it holds by its gravitational force—planets, moons, asteroids, meteors, comets.
mass—the amount of matter in a body.

INVESTIGATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 119. How may sun spots be seen?

Secure an old photographic negative or smoke a piece of window glass in the flame of a candle and view the sun. Often the larger sun spots may be seen in this way. They will appear as dark blotches on the bright surface of the sun. Record your observations in your notebook.

Activity 120. How may the planets be distinguished from the fixed stars?

A little practice in observing will help you to recognize the planets. They shine with a steady glow, and with a few exceptions the ones visible are the brightest bodies in the evening sky. Secure an almanac and find out which planets are evening stars and which are morning stars at the time when you wish to observe. Try to locate and identify some of the planets.

Record the day and hour of the observation and the name and position of each planet observed.

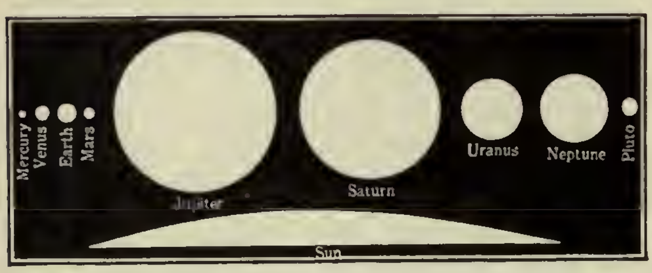
[1] See workbook, p. 67.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What heavenly bodies make up our solar system? In ancient times people thought that the earth made up the greater part of the universe. Even today it is hard for us to understand the true nature of our earth and its movements.

If we could transport ourselves far enough out into space we should see the earth as it really is—a huge object floating in space. We should notice that it is moving at a very rapid speed, eighteen and one-half miles per second or 66,600 miles per hour. If we continued to watch the earth long enough we should see that it is revolving around the sun. The path in which the earth moves around the sun is called the earth's *orbit.* The earth's orbit is six hundred million miles long, and 365¼ days are required for the earth to get completely around it.

From our position out in space we should notice many other bodies revolving around the sun. We now



From Astronomy *by Moulton. By permission of the Mocmillon Company, publishers.*

FIG. 296. RELATIVE DIMENSIONS OF THE PLANETS AND THE SUN

know that the earth is only one member of the sun's family. Circling in orbits around the sun are nine major planets, besides smaller planetoids, meteors, and comets. All these bodies with the sun make up the *solar system.* See Figure 298.

The sun is the dominant member of the solar system. Its mass is seven hundred times greater than the mass of all the members of its family combined. The planets, comets, and meteors are held in their orbits by the great *gravitational attraction* of the sun.

What is the nature of our sun? Our sun is a star. To us it looks much larger than the stars we see at night, but in reality it is just a medium-sized star. Our sun looks much larger because it is only about 93,000,000 miles away from us while the next nearest star is about 25,000,000,000,000 miles away. Compared to the size of the earth, however, the sun is enormous. The diameter of the sun is 865,000 miles as compared with 8,000 for the earth, and its volume is 1,000,000 times that of the earth. If the sun were represented by a basketball the earth would be about the size of a pea. If the earth with the moon revolving around it could be placed at the center of the sun, the orbit of the moon would be only about half way to the surface of the sun.

If we look at the sun through a smoked glass it appears as a great, bright disk, but through a telescope interesting features appear on its surface. Figure 297 is a photograph of the sun. Notice the dark markings at various places. These are called *sun spots.* Exceptionally large sun spots can be seen through a smoked glass without the aid of a telescope. Astronomers by constant watching have found that sun spot activity

Courtesy Mount Wilson Observotory

FIG. 297. A PHOTOGRAPH OF THE SUN
Note the sun spots.

varies. In some years hardly a spot can be seen. Then the spots appear more often. In about five years from the time only a few spots are visible on the face of the sun, many sun spots develop. After this the sun spots gradually disappear. This fading away and appearance again of great sun spots requires a period of about eleven years. During the time of great sun spot activity interesting things happen on the earth. Compass needles are affected. Electrical energy liberated by the sun spots interferes with our radio reception and our communication by telephone and telegraph. Brilliant displays of the aurora borealis (northern lights) are common. Some scientists think that there may also be a connection between weather phenomena on the earth and sun spot activity which, if under-

stood would, aid in the matter of weather prediction.

The chemical composition of the sun has also been determined, an achievement which less than a hundred years ago was thought impossible. Every chemical element in the gaseous state gives off its own distinctive kind of light. By means of the *spectroscope*, a marvelous instrument that separates light from any source into its parts, scientists determine what chemical elements are in the sun or any other star. It is certain from an analysis of sunlight that the sun is composed of enormous quantities of nearly all the elements, such as iron, copper, zinc, carbon, nickel, oxygen, hydrogen, etc., that are known on the earth.

We are dependent upon the sun for our existence. The sun is the source of practically all our energy. Without sunlight plants could not grow and manufacture food. Since animals depend upon plants for their food, no animals could exist on the earth without sunlight. Even the wood, coal, gas, and oil we use for fuel possess energy obtained from the sun at some time in the past. When coal burns it releases energy that plants obtained from the sun millions of years ago. Nearly all the energy and forces man directs on the earth have their origin in the sun. Because the heat of the sun evaporates large quantities of water into the atmosphere, we have streams and waterfalls. These man harnesses to run dynamos and generate electricity which furnishes us with light and heat in our homes. When we work and play we are directing energy that was received by plants from the sun. Can you think of any form of energy, on the earth, that does not originate in the sun?

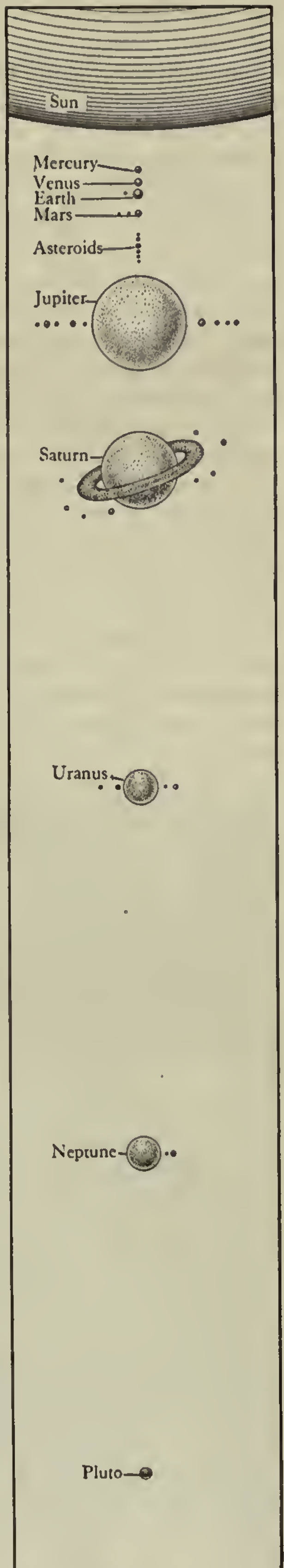


FIG. 298. COMPARISON OF ORBITS OF THE PLANETS

The sun is a huge, globular, gaseous mass, and it is inconceivably hot. Its surface temperature is 10,000°F., and at the center the temperature rises enormously to 30,000,000°F. The sun has radiated heat and light upon the earth hundreds of millions of years, and scientists think that it will continue to radiate heat and light for millions of years in the future. The source of the vast amount of energy the sun gives out is still a mystery.

What has science learned of the planets? Revolving around the sun are nine major planets. Look at Figure 298. Notice that there are four planets with orbits quite close to the sun. These small planets are Mercury, Venus, Earth, and Mars, which taken together are known as the *earth-like planets.* The orbits of Jupiter, Saturn, Uranus, and Neptune are farther away from the sun; these large planets are called the *great planets.* The most recently discovered planet, Pluto, is farthest from the sun. Notice also that the orbits of all the planets lie in the same plane and that they all move in the same direction in their orbits. Some details about each planet will be given in the following paragraphs.

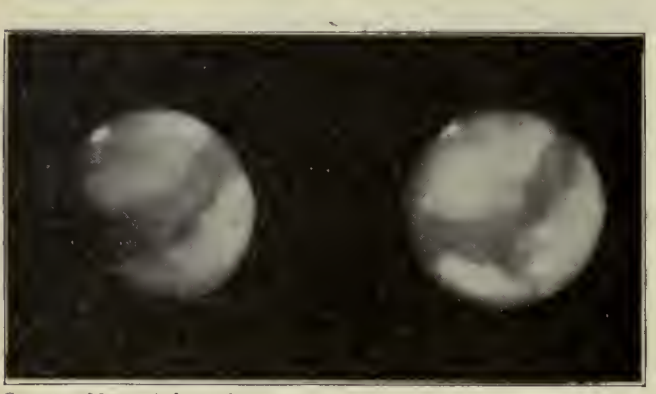
Mercury. Mercury, the smallest of the nine major planets, is the nearest to the sun. Its average distance from the sun is about thirty-six million miles. Like all the other planets it is named for a heathen god. Because this planet moves so swiftly, it was named for the messenger of the Roman gods. It travels between twenty-three and thirty-five miles a second and requires only eighty-eight days to complete one revolution about the sun. It is not known whether Mercury rotates on an axis. If it does not, the side toward the sun must be a burning desert and the other side a frozen waste. Mercury has little or no atmosphere. Because of its small size, its gravitational attraction is not sufficient to hold an atmosphere to it.

Venus. Venus is more like the earth than any other planet. It is almost as large as the earth and it has an atmosphere nearly as dense as ours. Because the atmosphere of Venus is always cloudy, no definite markings on the surface can be seen. This makes it difficult to determine how much time is required for it to make one rotation on its axis. At present it is thought that the period of rotation of the planet Venus is long in comparison with that of the earth. Therefore one side of the planet is very hot and the other side very cool. Since Venus has an atmosphere and is farther from the sun, the difference in temperature of the two sides would not be so great as on Mercury.

With the exception of our sun and moon, Venus far outshines any other heavenly body. Sometimes it comes up in the east before the sun, and it is then called the morning "star." For several months it appears after sunset in the west, and it is then called the evening "star." Of course it is not a star because it shines by reflecting light from the sun. Stars are self-luminous bodies.

Earth. The earth is the largest of the earth-like planets. It is about 8,000 miles in diameter and 25,000 miles around at the equator. It rotates on its axis once in twenty-four hours and completes its revolution around the sun in 365¼ days. More information about the earth will be given in the next topic and also in the next unit.

Mars. Mars perhaps has excited more interest than any other planet, and many persons wonder whether there are living things upon it. Before considering the possibility of life on this planet, however, it is necessary to know some facts about it. The diameter of Mars is about half that of the earth and its mass is only one-ninth as great. Because of its small mass, the gravitational force of Mars is much less than that of the earth. Hence it must have a thin atmosphere. Life as we know it also requires water and the proper temperatures. Astronomers have noticed the appearance and disappearance of white caps at the polar regions of Mars, which are thought by some to be ice caps, similar to the ice caps in the polar regions of the earth. It has never been conclusively proved, however, that the polar white caps are formed from water. Concerning the temperature of Mars it has been estimated that the sun's heat on Mars has about two-thirds the intensity of the heat which warms the earth. This would be sufficient heat for life, but since Mars has a very limited atmosphere, at night its surface must cool very rapidly and the temperature probably falls below the freezing point every night.



Courtesy Mount Wilson Observatory

FIG. 299. TWO VIEWS OF MARS
Notice the "ice caps."

In 1877 the Italian astronomer G. V. Schiaparelli announced the discovery of strange markings on the surface of Mars. He described them as long, narrow, straight dark streaks which he called "canali" (channels). Since Schiaparelli's time many other observers have claimed to have verified his observations. Some people with vivid imaginations have brought forward the claim that these markings on Mars are great canals constructed by engineers for running the melting snow water of the polar caps down toward the central regions of the planet for irrigation purposes. This view has been defended by men of great ability, but many other competent observers say they are unable to find evidences of such intelligent and extraordinary feats of engineering.

The only scientific conclusion we can come to at the present time concerning life on Mars is that there is a possibility that Mars supports life, but so far we have no direct evidence of life of any sort there. In fact, in many ways Venus is more like the earth than Mars, and it may be better able to support life.

Jupiter. Jupiter is sometimes called the giant planet because it is the largest. It is 86,000 miles in diameter and 317 times as massive as the earth. Jupiter is 483 million miles from the sun, so that the sun's rays which strike it have only one thirtieth of their intensity on the earth. Although Jupiter travels at the rate of eight miles a second, twelve of our years are required for it to make one revolution around the sun.

FIG. 300. JUPITER WITH ITS MOONS

Jupiter is an interesting sight through a small telescope. In addition to the planet four little moons that revolve about it in a row can be seen. They were the first objects in the sky discovered by Galileo in 1610 with the telescope he invented. Jupiter has five more moons, but they are so small that they are visible only through a large telescope.

Saturn. To the unaided eye Saturn appears like a yellowish star, but when viewed through a telescope it is one of the wonderful sights of the heavens. Saturn possesses a beautiful system of rings that encircle it (Fig. 301), and it is also attended by ten moons that revolve about it. Saturn has three rings. The diameter of Saturn itself is about 70,000 miles, but the diameter of its outer ring is 167,000 miles. The rings are very thin, the outer one having a thickness of about ten miles. The exact nature of these rings is not known. Moulton, a noted American astronomer, thinks they are swarms of bodies individually small and probably dust-like in character.

Uranus. All the planets described thus far have been known for many centuries. It was thought that Saturn was the most distant planet until 1781, when William Herschel, a German musician, discovered Uranus.

Because of the great distance of Uranus from us, it has been difficult to make observations of its features. It seems, however, to resemble Saturn and Jupiter. Four moons are known to revolve about this planet.

Neptune. The discovery of Neptune is one of the most dramatic events in the history of science. Uranus was discovered accidentally, but Neptune was discovered by the aid of a mathematician in his study. Soon after the discovery of Uranus the size and position of its orbit were determined and its motion was carefully followed by observers. As years went by, astronomers noticed to their surprise that Uranus did not stay in its computed orbit. By 1820 it was suggested that the peculiarities in the motion of Uranus might be due to the gravitational attraction of some unseen, distant body, and the problem was to calculate where the trouble maker was. Because of the great mathematical difficulties involved, some astronomers thought the problem could not be solved. But the problem was attacked and solved independently in 1846 by Adams, an Englishman, and Leverrier, a Frenchman. Although Adams finished his work first, the work of Leverrier led to the discovery of Neptune. Leverrier communicated his work to Galle, a German astronomer who in the evening of February 23, 1846, pointed his telescope toward the sky and found the planet Neptune in almost the exact place Adams and Leverrier had predicted it would be. The discovery caused a sensation.

Courtesy Mount Wilson Observatory

FIG. 301. TWELVE EXPOSURES OF SATURN

Neptune is about 2,800 million miles from the sun and because of its great distance from the earth can be seen only through a telescope. Even the large telescopes do not reveal its surface clearly. It is approximately 36,000 miles in diameter. It moves in its orbit at the rate of three and one third miles a second and requires about 164 years to revolve in its orbit around the sun.

Pluto. After the discovery of Neptune in 1846 astronomers considered the possibility of the existence of planets still more remote from the sun. Percival Lowell, an American astronomer, became intensely interested in the problem of finding more planets, and he eventually calculated mathematically the probable position of an unknown body. After twenty-five years of searching, this planet was finally located on January 21, 1930, by C. W. Tombaugh, a young astronomer working in the Lowell astronomical observatory. The planet was found in almost the exact direction that Lowell predicted it would be.

The orbit of Pluto is different from those of the other planets. The orbit is inclined to the plane of the orbits of the other planets. The diameter of Pluto is estimated to be much less than that of the earth. Not much is known about its physical characteristics.

Exercise. *From your study of the conditions on the various planets as now known by the astronomers, list those planets upon which there might or might not be life, giving supporting reasons in each case.*

What are the characteristics of other members of our solar system? *The planetoids or asteroids.* Look again at Figure 298 and notice the wide space between the orbits of Mars and Jupiter. Notice also the hundreds of small bodies revolving about the sun in this space. These bodies are called planetoids by some writers and asteroids by others.

Most of the planetoids are very small in comparison to the planets. Only a few of them have diameters exceeding one hundred miles. Astronomers are not yet able to determine the masses of the planetoids, but certain facts indicate that they are solid bodies.

Comets. All the members of the solar system that we have considered thus far move in more or less circular orbits around the sun, and they all have spherical or nearly spherical shapes. Comets are also members of our solar system because they move under the

influence of the sun's gravitation, but they differ from planets in a number of ways.

When a comet is visible to the unaided eye it has a head and a tail. As it moves toward the sun the tail

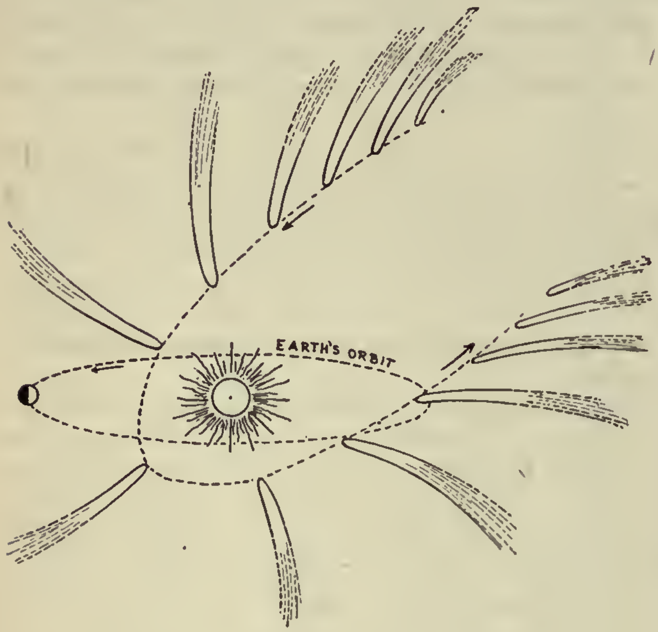


FIG. 302. ORBIT OF A COMET

is back of the head, but as it moves away the tail is directed away from the sun. Most comets are not visible to the naked eye and many do not have a bright head or a tail but appear as faint, hazy patches in the sky. Halley's comet (Fig. 303), named after the English astronomer Halley, is perhaps the most famous comet of all. It is visible in the sky every seventy-six years. It appeared last in 1910 and will return in 1986. Some comets appear only once to us and then disappear, perhaps forever, because their orbits are not closed like the orbits of the planets.

Comets are the largest bodies of the solar system. The head of the great comet of 1811 was 1,150,000 miles in diameter. The tails of some comets have exceeded 100,000,000 miles in length, and a comet that appeared in 1843 had a tail over 200,000,000 miles long. Some of the light of comets is reflected sunlight and some of it comes from self-luminous material that they contain.

The matter in a comet is very thin. The tail and the outer edge of the head seem to be composed of very small gaseous particles and possibly some finely divided dust. The center of the head is composed of denser material, probably solid particles widely separated from each other. One astronomer estimates that in a cubic mile there is, on the average, probably not more than a half ounce of solid material.

Exercise. *For centuries many people have been afraid of comets because they think that one might collide with the earth and destroy it. Do you think these fears are justified? Comment on the facts about comets which are known to science.*

Meteors and meteorites. If one observes the sky on a clear, moonless night he may see occasional streaks of light in the sky that last a second or two and are gone. These are *meteors,* but they are often improperly called "shooting stars." Although the meteors seem to dart out from among the stars, they are not stars at

Courtesy Yerkes Observatory

FIG. 303. HALLEY'S COMET

all. They are bits of dust or metal, perhaps like grains of sand, which belong to our solar system. They are members of the sun's family, moving swiftly through space, that come into the atmosphere of the earth. Rushing through the air with great speed, the friction they produce with the atmosphere heats them to white heat and destroys them.

Swarms of meteors travel about the sun. If their orbits cross the earth's orbit, a meteor shower is seen each year at the time when the earth reaches the intersection of the two orbits. Perhaps the best known meteor shower is the Leonids. Each year a few of the Leonids are seen in November, but a great display takes place every thirty-three years, that being

the time required for the Leonids to complete their circuit around the sun.

Occasionally very large meteors streak across the sky, producing a brilliant phenomenon called a fireball. The portions that reach the earth's surface are called *meteorites*. Thousands of meteorites are now pre-

American Museum of Natural History

FIG. 304. THE CAPE YORK METEORITE
(Weight, 36½ tons)

served in museums. One, weighing 36½ tons, found by the late Admiral Peary in Greenland, is now in the American Museum of Natural History in New York City. The largest known meteor, which was found in Mexico, weighs approximately fifty tons.

Meteorites are roughly divided into three classes: the iron meteorites, composed mainly of iron and nickel; the stony iron meteorites, in which iron and nickel are mixed with stony materials; and the stony meteorites, which consist essentially of stony material with only minor amounts of metals in them.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 16
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 11
Hunter and Whitman, *Science in Our World of Progress*, Unit 9; *Science in Our Social Life*, Unit 9
Lake, Harley, and Welton, *Exploring the World of Science*, Unit 5
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 1
Powers, Neuner, and Bruner, *This Changing World*, Chaps. 2 and 3; *Man's Control of His Environment*, Chap. 32
Skilling, *Tours through the World of Science*, Tour 6
Van Buskirk and Smith, *The Science of Everyday Life*, pp. 299-301
Watkins and Bedell, *General Science for Today*, Chap. 9
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 6
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It*, Topics 2 and 3; *Our Environment: How We Use and Control It*, Topic 14

Special references

Collins, *The Book of Stars*
Martin, *The Friendly Stars*
Lewis, *Astronomy for Young Folks*
Proctor, *The Young Folk's Book of the Heavens*
MacPherson, *The Romance of Modern Astronomy*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the nature of our sun, and its relation to other bodies of the solar system.
2. A knowledge of the planets.
3. A knowledge of the other members of the solar system: comets, meteors, and asteroids.
4. Ability to recognize the various visible planets.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The force which holds the planets in their orbits is called ____.
2. The center of our solar system is the ____.
3. The planet which most nearly resembles the earth is ____.
4. "Shooting stars" should be called ____.
5. If life exists on any other planet, it is probably on ____ or ____.
6. The planets in order of their distance from the sun are ____.
7. The planet ____ is closest to the earth.
8. The smallest planet is ____.
9. What has science learned of particular interest about the planet Jupiter?
10. Saturn has ____ rings. The outer ring is about ____ miles in thickness.
11. Morning and evening stars are in reality ____.
12. The planet Venus is between the earth and the planet ____. It is (smaller, larger) ____ than the earth. The surface of Venus is invisible from the earth because of its____.
13. Asteroids are ____.
14. Meteors are caused by ____ coming in contact with ____ and being heated by the ____.
15. Explain what a comet is.

TOPIC 3. OUR EARTH, A PLANET

SUGGESTED PROBLEMS AND QUESTIONS

1. What kind of heavenly body is our earth?
2. Why does the moon appear to change its shape?
3. What are the effects of the moon upon the earth?
4. What are the causes of eclipses?
5. What causes day and night?
6. What causes the seasons of the year?
7. How is time kept?

SUGGESTIONS AND HELPS FOR STUDY

1. In studying the material of this topic you will find the diagrams and pictures helpful. Study them closely.

2. It is difficult at first to understand why the moon always turns the same face toward the earth. This is because the moon turns once on its axis while it is making a revolution about the earth. See if you can demonstrate this point by an experiment.

3. In studying this topic try to form a mental picture of the motions of the earth and moon in space. It will help to clarify some of the more difficult points.

4. You may find the following new words and phrases in this study:

axis—an imaginary line which passes through a body upon which the body is supposed to turn or rotate.

equinox—the time when the sun crosses the equator, occurring about March 21 and September 22 each year.

neap tides—tides occurring at the first and third quarters of the moon.

spring tides—tides occurring at new and full moon.

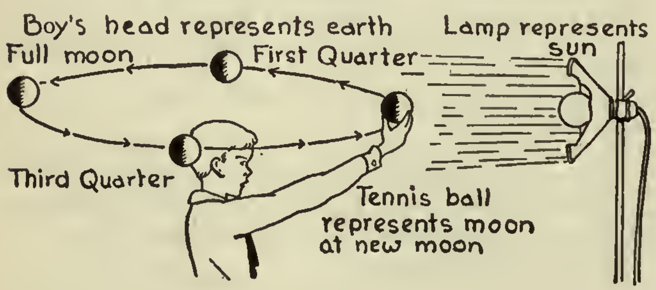


FIG. 305

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 121. Does the moon actually change its shape?

Secure an electric-light globe and a tennis ball or baseball as pictured in Figure 305. The electric light is to illustrate the sun, you are the earth, and the ball represents the moon. A candle may be used in place of the electric light for the sun. With the light well above your head and to your back, hold the ball at arm's length, sufficiently high to receive light from the lamp. Observe the amount of the ball that is lighted. Slowly turn from right to left, holding the ball exactly in front of you until you have made one complete turn about. Observe the amount of illumination of the moon and how it changes as you turn. Repeat this several times until you see clearly why the moon appears to change shape as it turns about the earth.

Again repeat the turning, but this time sketch in your notebook the appearance of the part lighted at each quarter turn.

At the start of this experiment the moon is represented at ____ quarter. When a quarter turn has been made from the starting position it has reached ____ quarter. Another quarter turn brings it to ____. Full moon is ____ quarter and new moon is ____ quarter. New moon occurs when ____. Full moon occurs when ____.

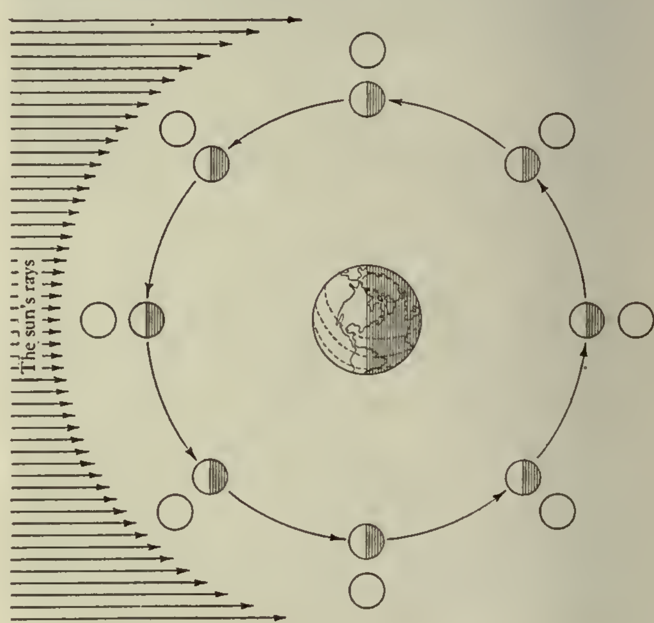


FIG. 306

In figure 306 the inner circle shows the amount of the moon lighted at different times in its trip around the earth. Copy the figure in your notebook and shade in the dark portion of the moon in each of the outer circles so that it shows the shape of the moon, as seen from the earth, to correspond with the amount of illumination in each circle shown in the inside ring.

Experiment 122. What causes eclipses?

In a partly darkened room set an electric lamp on a desk as shown in Figure 307. Again this represents the sun. A candle may be used in place of the lamp.

On a piece of light cardboard draw a circle about six inches in diameter and place this three or four feet away from the sun. This represents the earth; if you wish you may draw in the outlines of the continents to make it more real. A geographical globe may be used instead of the cardboard earth. Set the cardboard upright as shown in the illustration.

[1] See workbook, p. 68.

Secure a rubber ball about an inch and a half or two inches in diameter, and through it stick a piece of wire about six inches long. This ball represents the moon. Now move the ball representing the moon around the earth about six inches from it, from right to left as you face away from

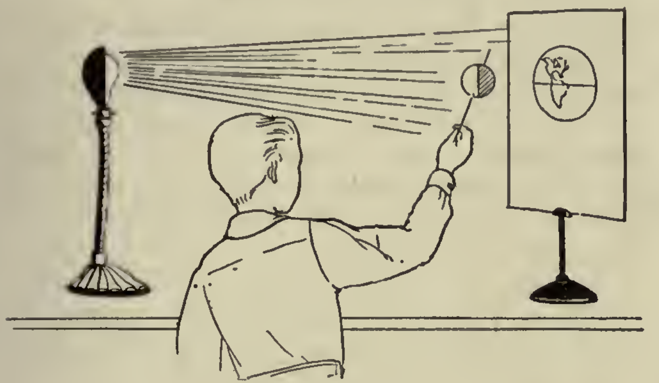


FIG. 307

the sun. When the moon gets between the earth and sun, observe what happens on the earth.

Carefully observe the shadow as it begins and then as it develops and finally passes off the earth. Repeat this and make drawings to represent the appearance of the shadow as it covers the earth. Make at least two drawings. If you are using a globe for the earth, interchange it with the ball representing the moon, and by moving the latter, show how a lunar eclipse may be formed.

Make two drawings, one showing how lunar and the other how solar eclipses are formed.

Solar eclipses can occur only at new moon. Give an explanation of this.

Lunar eclipses can occur only at full moon. Give an explanation of this.

Could a solar eclipse be observed at night or a lunar eclipse in the day time? Explain your answer.

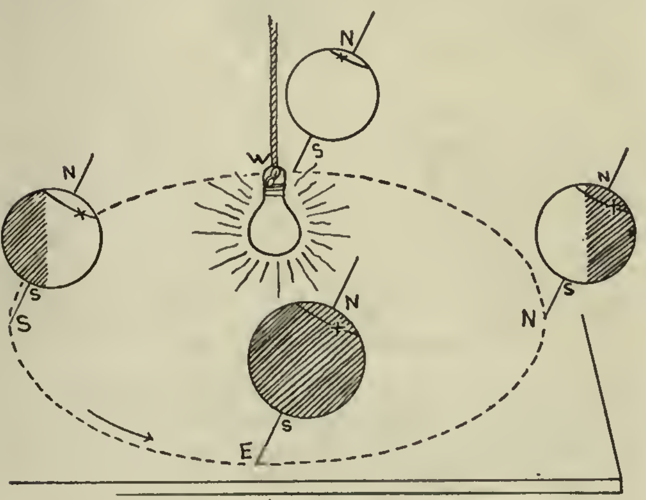


FIG. 308

Experiment 123. Why do days and nights change in length from season to season?

In a darkened room set up the equipment as illustrated in Figure 308. The earth is represented by a two-inch rubber ball or a tennis ball which has had a wire or knitting needle about six inches long pushed through it. The sun is placed at the center of a circle with a diameter of about fifteen inches which has been drawn upon a piece of cardboard or paper. This circle represents the earth's orbit or pathway about the sun. At the quarter points label the orbit "North," "East," "South," "West" as shown in the diagram. Draw a line around the earth-ball halfway between the north and south poles. This represents the equator. Now between the equator and north pole draw another line around the ball representing your latitude. On this line place a dot which might represent your locality.

Place the earth at the point of the orbit marked "South" and have the axis point as nearly as possible to the direction in which the North Star would be. How much of the surface of the earth is lighted by the sun?

Turn the earth on its axis in this position. Is the dot representing your locality in the light or shadow longer? At this season would the day or night be longer? What season are you having when this condition occurs?

Now move the earth through its orbit in the direction of the arrow to a position east of the sun. Be sure that the axis still points the direction of the North Star. How much of the earth's surface is now lighted by the sun?

Again turn the earth on its axis. Is the dot representing your locality in the shadow or light longer? At this season how would the length of day and night compare? What season would this represent?

Again move the earth in its orbit until it is north of the sun, and repeat the rotation on its axis at this point.

How much of the earth's surface is illuminated? Is day or night longer in the locality where the dot is? What season are you having when the earth is north of the sun?

Move the earth to a position in its orbit which is west of the sun. Repeat the rotation of the earth on its axis.

How much of the surface of the earth is here lighted by the sun? How do the days and nights compare in length at this season of the year? What season are you having?

With the equipment study the reasons for the six-month night and six-month day at the poles and determine when each occurs. Study the length of day and night at the different seasons of a city located on the equator. Repeat this for a city located in the southern hemisphere.

Write a short report, explaining clearly why days and nights are of unequal length in the northern hemisphere at different seasons of the year and also explaining the cause of the long polar days and nights.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What kind of heavenly body is our earth? Our earth is a great, nearly round ball about 8,000 miles in diameter. It is not a perfect sphere, because its diameter at the equator is about twenty-seven miles longer than its polar diameter.

Only a few centuries ago most people imagined the earth to be flat, and there still are a few persons who argue that it is so. When Columbus made his voyage to America, many persons believed that he would fall off the side of the earth. There are, however, good reasons which cause us to believe it is spherical in shape. (1) Ships sail completely around the earth. In fact, such cruises are regularly advertised today. Would this be possible if the earth were flat?

(2) The first part of a steamship that a person, standing at a harbor, sees is the funnels. The body of the ship comes into view last. This indicates that the earth's surface is curved, for if it were flat we should see the large body of the ship first. (3) The shadow of the earth on the moon when the earth comes directly between the sun and the moon is round. (4) Scientists have accurately measured the dimensions of the earth, and their measurements show that the earth is a sphere, slightly flattened at the poles. (5) Photographs taken of the earth on balloon flights to the stratosphere also indicate that the earth is a sphere.

Courtesy Bausch and Lomb Optical Company

FIG. 309. PHOTOGRAPH OF THE MOON

The weight of the earth has also been determined. Its weight was first determined by Cavendish, a celebrated English physicist, in 1798. In 1930 Dr. Paul R. Heyl of the United States Bureau of Standards repeated Cavendish's experiment. The earth weighs about 6,000 million million million tons.

The surface of the earth with its mountains and valleys looks very uneven. The highest mountain is Mount Everest, 29,141 feet. Canyons more than a mile deep roughen its surface, and the Pacific Ocean has a depth at one place of 35,430 feet. Yet on a twelve-inch model of the earth we should scarcely be able to notice these irregularities of the surface, and if we were able to view the earth from the sun it would appear only as a tiny speck in space.

Why does the moon appear to change its shape? The moon is about 240,000 miles from the earth. It is the nearest of the heavenly bodies. Its diameter is 2,160 miles, a little more than one-fourth that of the earth. It looks about the same size as the sun, but in reality the sun is 400 times larger. The sun is 400 times farther from the earth than the moon; hence it looks about the same size.

The naked eye sees many light and dark areas on the moon. Through a telescope the dark areas are smooth and the light areas are rough. Photographs of the moon taken with our largest telescopes show the surface of the moon to be very uneven and mountainous (Fig. 309). The dark areas are great plains, surrounded by great mountains. Some of the mountains are in chains that have been named after similar formations on the earth, such as the Alps and Caucasus. Others rise majestically as isolated peaks. Many of the mountains are from 1,000 to 2,000 feet in

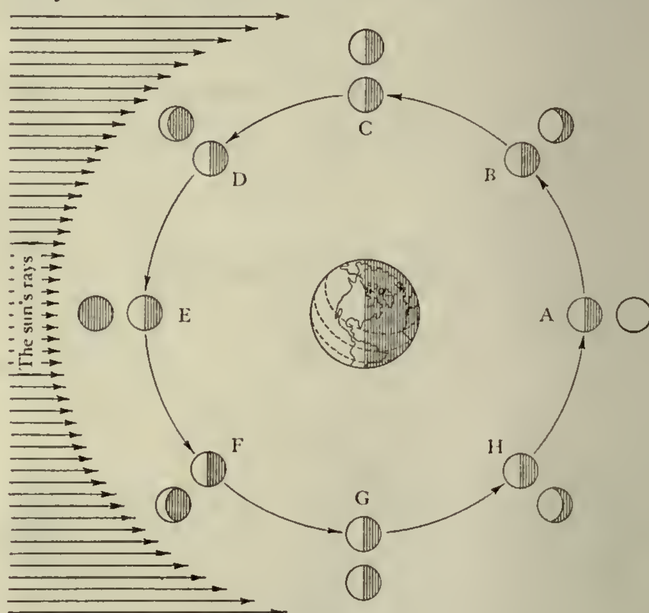


FIG. 310. PHASES OF THE MOON

height, and some have elevations over 25,000 feet.

There are thousands of formations on the moon that resemble the volcanic craters on the earth. They are called *lunar* or *moon craters*. It is not known, however, whether they are of volcanic origin, and there seems to be no volcanic action on the moon at the present time. The lunar craters vary in size from mere pits less than one eighth of a mile across to great depressions more than a hundred miles wide. Some of the larger craters have surrounding rims with eleva-

tions over 16,000 feet high. Often smaller craters are within the larger ones, and in many instances a single mountain or groups of mountains rise from the floor of a large crater.

The moon is a dead, barren place. It has no atmosphere, no water, and no living things on it. Like the planets it shines by reflected light. Since the moon rotates once on its axis in the same period of time that it revolves around the earth, it keeps the same side or face towards the earth all the time. Have you tried the experiment at the beginning of the topic which shows why this is so?

The moon completes one rotation on its axis in about twenty-nine days. Therefore the sun shines constantly on a region for two full weeks. During this time the temperature is believed to reach or perhaps exceed the boiling point of water. During the equally long night of two weeks, the temperature falls below —256°F.

The gravitational attraction at the surface of the moon is only one-sixth that of the earth. A person would weigh about one-sixth as much at the surface of the moon as on the surface of the earth. A boy who can throw a baseball one hundred feet high on the earth could throw the same ball at least six hundred feet high on the moon. A jumper on the moon could jump six times as high and six times as far as he could on the earth, assuming that he would be able to exert the same physical activity on the moon as he can on the earth.

Sometimes we see the moon as a thin crescent and sometimes it is big and round. Why is this? The moon is not a self-luminous body but shines like the planets by reflected sunlight. Also the moon revolves around the earth. It is on account of these two facts that the moon changes its appearance.

Study Figure 310 carefully as you read the following paragraphs and learn how the phases of the moon are produced. Think of the sun as far off to the left. The arrows show the rays coming from the sun. When the moon is at E, the point in its revolution where it is between the sun and the earth, the illuminated side of the moon is turned from the earth and we cannot see it. This is called *new moon*, which really means no moon.

About three days later the moon has moved in its orbit to position F. Now we can see a very small part of the illuminated side, and the moon appears as a crescent.

In about four more days the moon is at G. Then one half of the illuminated side is visible, or the moon is at *first quarter*.

About fourteen days after the moon is new, it is at A. In this position the earth is between the sun and the moon, so that the entire illuminated side of the moon is visible to us. This is *full moon*.

About twenty-one days after new moon, the moon is at C, when again only one half of the illuminated side is visible to us. This phase is called *last quarter*.

About seven days after last quarter, the moon is back at E and we have new moon again. The moon completes a revolution about the earth in twenty-nine and a half days.

What are the effects of the moon upon the earth? The moon reflects a large amount of sunlight upon the earth, especially during full moon. However, in comparison to the amount of sunlight received direct-

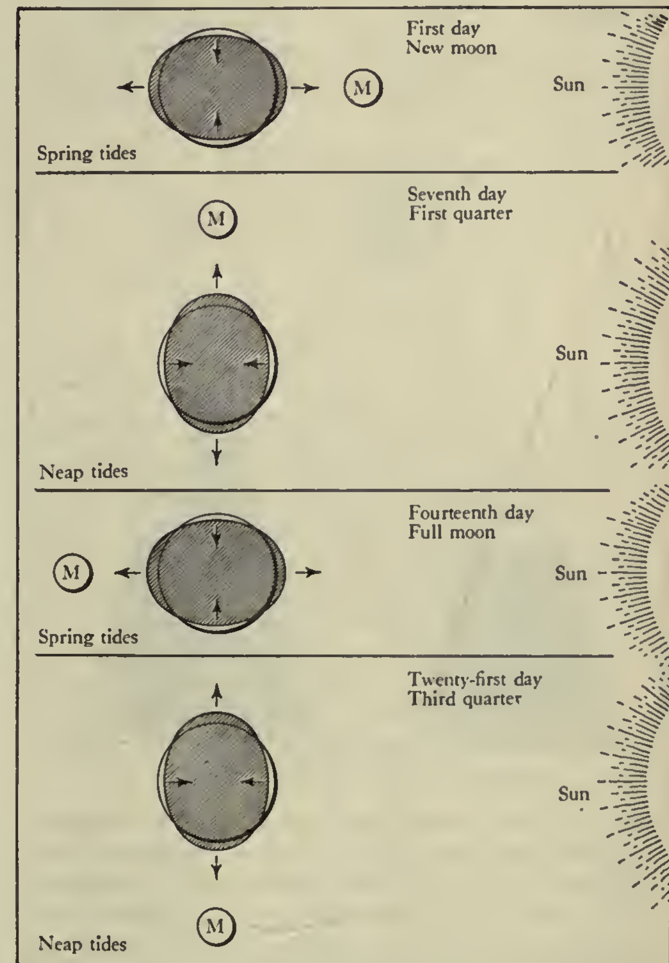


FIG. 311. CAUSES OF TIDES

ly by the earth from the sun, it is of little importance. The belief still persists, however, among many farmers that the moon has a direct effect upon crops. There is no foundation for this belief. It has been estimated that the earth receives more light from the sun in thirteen seconds than it does from the moon in one year. Accurate observations and records of the weather for long periods of time show no relationship whatsoever between the phases of the moon and climatic conditions.

Tides caused by the moon are perhaps its most

noticeable effects. People living near the ocean observe the waters of the open sea move in and rise on the shore, and then recede again. Twice every twenty-four hours and fifty-one minutes these phenomena take place. Tides are caused by the attraction of the moon and to a lesser extent by the attraction of the sun. The waters on the side of the earth nearest the moon are pulled outward, causing high tide. The waters on the directly opposite side of the earth, be-

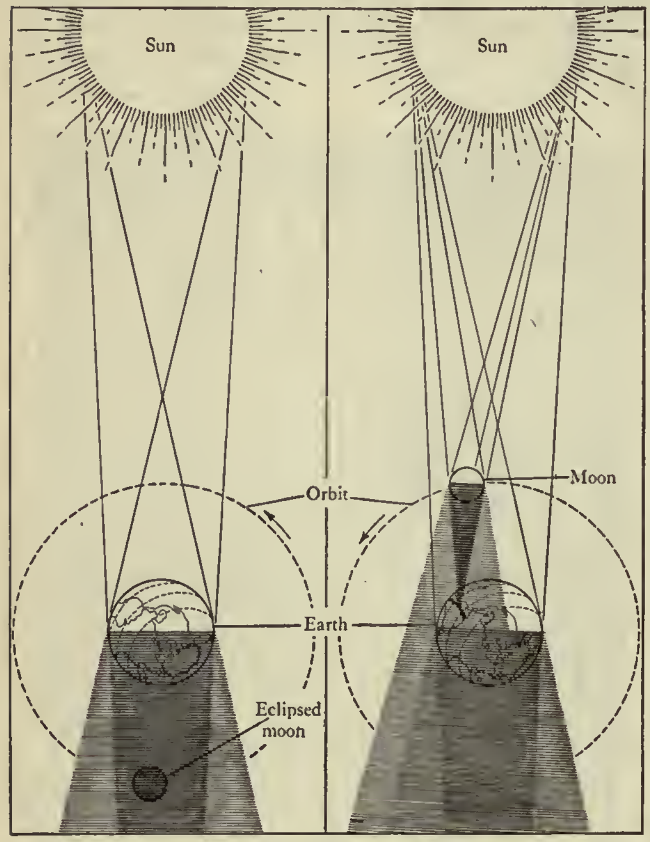


FIG. 312. ECLIPSES OF MOON AND SUN

cause of their greater distance from the moon, are attracted much less and lag behind, causing a high tide at that point. Low tides occur at places just halfway between these two points. The highest tides, called *spring tides,* occur when the sun, moon, and earth are in a straight line. The lowest tides, called *neap tides,* occur when the sun is at right angles to a line connecting the earth and the moon. See Figure 311. How often every month do neap tides and spring tides occur? The word *spring* in connection with tides has nothing to do with the season of the year called spring.

Tides have considerable practical value. In some places the energy of tides is used to run water wheels and machinery. High tides deepen certain shallow harbors, making it possible for large ships to enter. By keeping the water in motion tides help to keep some bays and harbors from becoming stagnant and impure. They wash the ocean shore twice a day and remove wastes that would otherwise accumulate. Certain fishing industries such as oyster and clam fishing secure beneficial effects from tides.

What are the causes of eclipses? Have you ever observed an eclipse of the moon or an eclipse of the sun? The ancients were much afraid during an eclipse, which they thought was caused by an angry god trying to blot out their source of light. Today most people have no fear or dread of these phenomena because we know their real causes, and we are able to calculate their appearances hundreds of years in advance. An eclipse of the moon occurs whenever the earth gets directly between the sun and the moon (Fig. 312). At this time the earth shuts off the sun's rays from the surface of the moon, which appears dark.

The eclipse of the sun is caused when the moon comes between the sun and the earth (Fig. 312). Most people have never seen an eclipse of the sun. Because the sun is a great deal larger than the moon and also because the moon is considerably smaller than the earth, the shadow cast by the moon covers only a small strip of the earth. If we happen to be inside this strip, none of the sun is in view, and we call the phenomenon a *total eclipse* of the sun. When a part of the sun remains visible it is called a *partial eclipse.*

What causes day and night? We commonly say that the sun rises in the east and sets in the west. But is the sun moving or are we moving? At night the stars also seem to move from east to west. Do the sun, the moon, and the stars really revolve about the earth once a day? They appear to, and the people of ancient times thought that they actually did. They were deceived. Have you ever sat in a passenger train and looked at another train nearby when both were standing still? When your train started to move it appeared as if the other train were moving backward, but in reality your train was moving forward, and the other train was standing still. It is just the same with the earth and the stars. It looks as if the sky, the sun, and the stars were moving from east to west, but actually the earth is turning from west to east. Carefully performed experiments have shown that the earth rotates on its axis once every twenty-four hours.

Since the earth rotates constantly on its axis, only one half the earth can receive direct rays from the sun at a time. Therefore night and day follow each other. At the equator of the earth the day is twelve hours long and the night twelve hours long. At the north pole and the south pole the day is six months long and the night six months long. Those of us who live in the north temperate zone know that the length of our days and nights varies. We shall see why in the next few paragraphs.

Exercise. *Explain why the days and nights at the equator are always of equal length.*[1]

Exercise. *Cite evidence to support or disprove this statement: There are places on the earth other than exactly at the poles where during some months each year the sun never rises and during other months it never sets.*

Exercise. *A newspaper report recently stated that a baseball game was played in a certain part of North America at ten o'clock in the evening without the aid of artificial illumination. Suggest the general location of the place in which the game might have been played.*

What causes the seasons of the year? The earth revolves in its orbit about the sun. The earth completes 365¼ rotations upon its axis while it is revolving once around the sun. Thus our year is 365¼ days long.

The seasons are due to the fact that the earth's axis is inclined at an angle of 23½ degrees towards the plane of its orbit (Fig. 314) and also because the axis always points towards the North Star. If the earth's axis were not inclined or tilted, there would be no seasons, because the direct rays of the sun would always strike the equator, and days and nights would be equal everywhere, every day of the year.

Figure 314 gives the positions of the earth in relation to the sun at the different seasons of the year. There are only two days in the year, about March 21 and about September 22, when the earth's axis is not inclined toward or away from the sun. On these two dates the rays of the sun fall perpendicularly upon the equator, and every place on the earth has twelve hours of daylight and twelve hours of darkness. March 21 is called the *spring* or *vernal equinox* and September

Courtesy Science Service

FIG. 313. PHOTOGRAPH OF THE SUN IN ECLIPSE

22 the *fall* or *autumnal equinox*. As the earth continues its course in its orbit after March 21, the upper end of its axis shifts, from day to day, towards the sun. On June 21 the rays of the sun fall vertically on the tropic of Cancer, 23½ degrees north of the equator. At this time all of the arctic circle receives the sun's rays, while the antarctic circle is in darkness. June 21 is called the *summer solstice*. At this time the day for all places north of the tropic of Cancer is more than

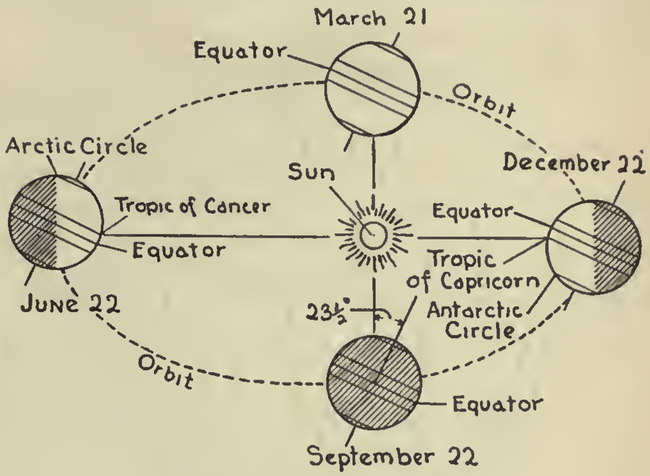


FIG. 314. SEASONAL INCLINATION

twelve hours long, and we have our summer. The day for all places south of the tropic of Capricorn is less than twelve hours long, and people living in the south temperature zone have their winter.

From June 21 to September 22 the days again become shorter. The upper end of the earth's axis on September 22 is again pointing neither away from nor toward the sun. The sun's rays fall directly on the equator, and days and night are equal everywhere on the earth. September 22 is the *fall equinox* and marks the beginning of the fall season.

In the northern hemisphere from September 22 to December 22 the tilt of the earth away from the sun is slightly more each day. On December 22 the sun's rays strike directly on the tropic of Capricorn, 23½ degrees south of the equator. This is the *winter solstice*. We have our shortest day and our longest night. The entire antarctic circle is in daylight and the entire region of the arctic circle is in darkness. December 22 is the first day of winter for us and the first day of summer in the south temperate zone. Thus the seasons in the countries south of the tropic of Capricorn are always the reverse of ours.

As the earth continues in its orbit from December 22, the days increase in length and the seasons are repeated.

Why is summer warmer than winter? The earth's orbit is not a circle, but an *ellipse*. The sun is not exactly at the center of its orbit. The differences in temperature between summer and winter are not due,

[1] See workbook, p. 71.

however, to the distance of the earth from the sun. Strange as it may seem, we who live in the north temperate zone are actually about 3,000,000 miles nearer the sun in winter than in summer.

There are two reasons for the difference in temperature at different seasons of the year. (1) During the summer season a given portion of the earth receives more heat and light than in the winter because the rays of the sun strike the earth more directly. During the winter season the sun's rays strike the earth more slantingly. As a result they spread over a greater amount of surface and are less intense. (2) In summer the days are longer than in winter. Thus we receive more hours of sunlight each day.

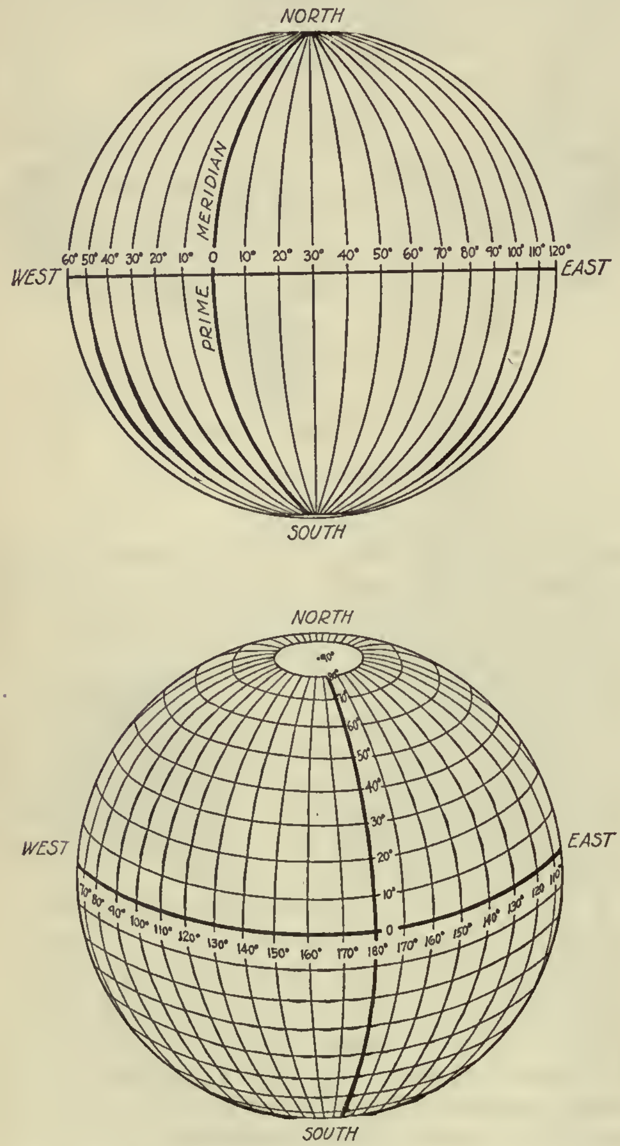


FIG. 315

Exercise. *Explain why the countries in the Southern Hemisphere have winter while we have summer and summer while we have winter.*[1]

To make it possible to locate places on the earth and for convenience in reckoning time, the earth's equator is divided into 360 equal parts called degrees (°). Each degree is divided into sixty minutes (′), and the minute is further divided into 60 seconds (″). See Figure 315. Imaginary lines extending from the north pole to the south pole through each degree are drawn on maps of the earth. These imaginary lines, which are called *meridians,* indicate degrees of *longitude.* By international agreement, the meridian passing through Greenwich (gren′ich), England, is called zero meridian or *prime meridian* and is marked 0°. From this point the meridians are numbered east and west from 0° to 180°, making a total of 360 degrees.

Likewise at every degree north and south of the equator imaginary lines are drawn parallel to the equator. These lines, which are called *parallels,* indicate degrees of *latitude* (Fig. 315). By means of parallels and meridians it is possible to locate any spot on the whole surface of the earth. Locate the position of your own home on the earth by reading latitude and longitude degrees on a map.

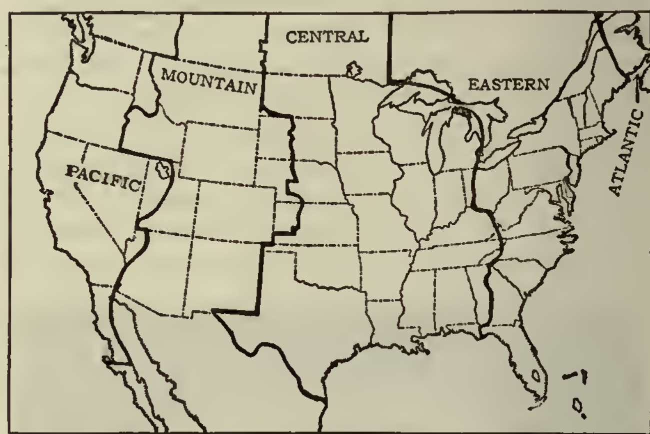


FIG. 316. STANDARD TIME BELTS IN THE UNITED STATES

How is time kept? Timekeeping is based upon the earth's movements. The rotation of the earth, completed regularly in about twenty-four hours, determines our day and night. Astronomers have shown that the time of rotation of the earth upon its axis has not changed appreciably for thousands of years. The revolution of the earth about the sun determines the length of our year.

Sun time is reckoned from noon to noon. Noon at any spot on the earth is the exact time in the day when the sun is nearest overhead. The meridian of that place is directly under the sun, and all places located on that meridian have noon at the same time. Places

[1] See workbook, p. 72.

east of that meridian have afternoon and places west have forenoon. Thus when it is twelve o'clock noon in Minneapolis it is afternoon in New York City and forenoon in Los Angeles.

Since the earth rotates on its axis once in twenty-four hours, it rotates 1/24 of 360 degrees, or 15 degrees, in one hour. If we wanted to keep our watches and clocks accurately timed according to the earth's rotation, we should have to set them back four minutes for every degree of longtitude we travel westward or put them ahead four minutes for every degree longitude we travel eastward. To avoid the confusion this would cause in commerce and travel, *standard time* was adopted in 1884. The country was divided into four districts or time belts. The time in each district was made one hour earlier than the district to the east of it and an hour later than the district to the west of it. These four times are called Eastern, Central, Mountain, and Pacific Standard times. The map in Figure 316 shows the time belts of the United States. The 75th meridian, passing through Philadelphia, is the starting point. All places east and west within a half hour of the local time of the 75th meridian use the local time of this meridian. This is the eastern time belt, and its time is known as Eastern Standard Time. Going westward we find the central time belt, the mountain time belt, and the Pacific time belt, which have the local times of the 90th, 105th, and 120th meridians, respectively. It should be noticed on the map that the boundaries of the different time belts are not exactly on the meridians just mentioned. The dividing lines are not straight, but are arranged to correspond to division points of the railroads, thus avoiding inconvenience in operating the railroads. The same general plan is used now throughout practically the entire civilized world.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chaps. 17 and 18
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 11
Hunter and Whitman, *Science in Our World of Progress*, Unit 9; *Science in Our Social Life*, Unit 9
Lake, Harley, and Welton, *Exploring the World of Science*, Unit 5
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 1
Powers, Neuner, and Bruner, *This Changing World*, Chap. 4; *Man's Control of His Environment*, Chap. 29
Skilling, *Tours through the World of Science*, Tour 6
Van Buskirk and Smith, *The Science of Everyday Life*, pp. 302-311
Watkins and Bedell, *General Science for Today*, Chap. 10
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 6
Wood and Carpenter, *Our Environment: How We Adapt Ourselves to It*, Topic 4; *Our Environment: How We Use and Control It*, Topic 14

Special references

Fabre, *The Story Book of Science*
Fabre, *This Earth of Ours*
Seeley, *The Story of the Earth*
Washburne, *The Story of the Earth*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the cause of the phases of the moon.
2. The cause of lunar and solar eclipses.
3. The causes of ocean tides.
4. The cause of day and night.
5. The cause of the change of seasons.
6. How time is kept.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The phases of the moon are ____.
2. When the moon is at *A* (Fig. 310) its phase is spoken of as ____.
3. When the moon is at *D* its phase is spoken of as ____.
4. The moon is in first quarter when it is at ____.
5. The moon is at full when it is at ____.
6. The length of day on the moon is ____ days and the length of night is ____.
7. The sun crosses the equator on ____ and ____.
8. Lunar eclipses may occur only at ____ moon, and solar eclipses only at ____ moon.
9. Partial eclipses are caused by ____.
10. Show, by means of a diagram, how a solar eclipse is total only for a small portion of the earth.
11. Explain why days and nights are of unequal length at different times of the year.
12. On what dates are day and night of equal length?
13. Why do the seasons change?
14. Why do we have our warmest weather in summer even though we are farther from the sun than in the winter?

SUPPLEMENTARY MATERIALS

Reading suggestions

Darrow, *Masters of Science and Invention* (Harcourt)
Gibson, *Heroes of Science* (Lippincott)
Collins, *The Boy Astronomer* (Lothrop)
Proctor, *The Young Folk's Book of the Heavens* (Little)
Lewis, *Astronomy for Young Folks* (Duffield)
Murphy, *A Beginner's Star Book* (Putnam)
MacPherson, *The Romance of Modern Astronomy* (Lippincott)
MacPherson, *Modern Astronomy* (Oxford)
Rogers, *Earth and Sky Every Child Should Know* (Grosset)
Serviss, *Astronomy with the Naked Eye* (Harper)
Jeans, *The Mysterious Universe* (Macmillan)

Jeans, *The Stars in Their Courses* (Macmillan)
Jeans, *The Universe Around Us* (Macmillan)
Jeans, *Through Space and Time* (Macmillan)
McFee, *Secrets of the Stars* (Crowell)
Harrison, *Daylight, Twilight, Darkness, and Time* (Silver)

Reports which may be prepared

1. Dwarf and giant stars
2. The discovery of Neptune
3. The spectroscope and how it aids the astronomer
4. Telling time
5. Harnessing the tides
6. Historic comets
7. A rocket trip to the moon
8. A trip to Mars
9. The rings of Saturn
10. What we know of spiral nebulae
11. The asteroids
12. The nebular hypothesis
13. The planetesimal hypothesis
14. The giant sun
15. An eclipse of the sun
16. Astronomical observatories
17. Astronomical instruments
18. How space is measured
19. The stuff that stars are made of
20. Star legends and myths
21. The building of the new 200-inch telescope
22. The calendar

Great scientists you should know about

1. Ptolemy
2. Copernicus
3. Galileo
4. Isaac Newton
5. Johann Kepler
6. Tycho Brahe
7. William Herschel
8. John Herschel
9. Percival Lowell
10. Pierre Laplace

Investigations and things to do

1. Learn to photograph the heavenly bodies.
2. Make a star finder.
3. Make a planisphere.
4. Make a simple refracting telescope.
5. Make a reflecting telescope.
6. Learn to plot the path of a planet.
7. Make a model of the solar system, using balls of different sizes to represent the planets.

UNIT IX. ROCKS AND SOILS OF THE EARTH

As we travel over the earth's surface we notice a variety of conditions. Large continents with great oceans surrounding them, high mountains along the borders of the continents, hills, valleys, plains, plateaus, deserts, rivers, and lakes attract our attention. How has our earth come to be as it is? Scientists are at work trying to answer this very question.

The earth's surface has been, for a long time, and is now constantly changing. Agents of erosion such as running water, wind, and moving ice wear away the surface of the earth at higher elevations and transport the material to regions of lower elevation. In addition to these forces that are wearing down the surface of the earth, certain internal strains and forces are at work elevating parts of the land. The irregular surface of the earth which we see today is the result of these two opposing forces. The struggle between these contending forces is still going on, and what the final result will be no one knows.

While erosive agents sometimes prove detrimental to man's welfare, they have, at the same time, been of inestimable benefit to him. They wear away the rocky hillsides and transport the material to the valleys and help to produce our fertile fields. Nature has been working for millions of years producing the soils upon which we raise our crops. Practically all of the earliest civilizations were established in fertile river valleys, and even today most of the people of the earth are congregated in or near crop-producing regions.

There are other interesting things such as volcanoes and earthquakes which we shall study in this unit. Early people had fanciful and superstitious notions which they invented to explain these phenomena. Earthquakes, for example, were thought to be the result of struggles between gods or giants beneath the earth's surface. Early peoples failed to make careful observations. Today our ideas about earthquakes and volcanoes are based upon carefully collected facts about them. And while we cannot control earthquakes or volcanoes, we can understand what causes them and attempt to make an intelligent adjustment to them.

Living things are dependent upon soil for their existence. The food materials of plants and animals, for the most part, come directly or indirectly from the soil. For several thousands of years agriculture has been one of our basic industries. Man is constantly occupied with the problem of maintaining soil fertility and finding new lands for farming. In this unit you will have the opportunity to study the factors which must be regulated in order to raise crops successfully.

In this unit we wish you to learn more about the points so briefly sketched in this introduction. The story of the earth is an interesting one, and the topic of soils is as important and closely related to human welfare and existence as any in the entire course.

What do you already know about rocks and soils?

1. What different kinds of rocks do you know?
2. Have you ever collected rocks and minerals? What did you learn from the experience?
3. Did you ever see a rock with shells or other animal remains in it? How did they get there?
4. Did you ever see rock that could be separated into layers? How was this formed?
5. How was coal formed?
6. What are some of the agents at work wearing away the earth's surface?
7. Large round boulders are often found on the tops of mountains. Can you explain how they may have got there?
8. Can you account for the formation of soil if the earth was once a barren, rocky surface?
9. How was the earth formed?
10. Why are rivers and streams always muddy at flood stage and after rains?
11. What is a nebula?
12. How old is the earth?
13. How are forces at work building up the earth's surface?
14. Do volcanoes open to the center of the earth? Give reasons for your answer.
15. Are the Rocky Mountains older than the Appalachian Mountains? Give reasons for your answer.

TOPIC 1. HOW ROCKS WERE FORMED

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is the age of the earth?**
2. **How was our earth formed?**
   a. **What is the Laplacian hypothesis?**
   b. **What is the planetesimal hypothesis?**
3. **What is the composition of the earth?**
4. **What are the main classes of rocks?**
   a. **What are igneous rocks?**
   b. **What are sedimentary rocks?**
   c. **What are metamorphic rocks?**
5. **What are fossils?**

SUGGESTIONS AND HELPS FOR STUDY

1. Read carefully the problems listed above. Are they questions you have ever wondered about or are now interested in?

2. The answer to problem 1 is not definitely known. Various estimates of the age of the earth have been made, however.

3. In connection with problem 5 try to find some fossils in your neighborhood. Look in sedimentary sandstone and limestone.

4. Problem 4 should be studied with actual specimens of sedimentary, igneous, and metamorphic rocks at hand.

5. Books have been written that will tell you how to identify rocks and minerals. Consult your teacher about them.

6. In the study of this topic the following words may be new or difficult for you. Study them carefully and use them as often as possible.

crystalline—formed of crystals.
erode—to wear away.
fossil—remains or imprints of plant or animal life in rock.
hypothesis—a guess or speculation.
sedimentary—formed of sediment.
soluble—able to be dissolved.
strata—layers of rock.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Activity 124. What kinds of rock are found in the region in which you live?

Make a collection of all the different kinds of rock that can be found in your community and identify as many as possible. Examine them closely with a magnifying lens. Are they solid in structure or are they made up of separate grains? Are the grains rounded or angular (with sharp edges)? Do any of the rocks consist of crystalline grains? Are the grains in layers or scattered? Test the hardness of the rock with the point of a knife blade. Assemble your information in your notebook.

Activity 125. Where are fossils found?

Imprints or the remains of plant and animal life in rock are called *fossils.* Fossils are abundant in limestone, sandstone, and coal. Explore any quarries in your neighborhood. Examine the rock ledges exposed. What kinds of rock are in them? Do the rocks contain any fossils? Suggest how these plant and animal remains may have come here.

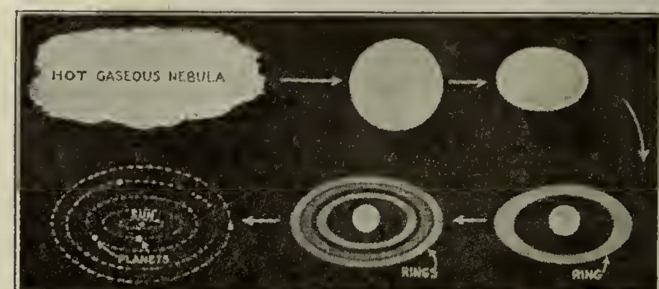
In your notebook, make drawings of the fossils found.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Explore any quarries that are in your neighborhood. Examine the rock strata that are exposed.
2. Make a collection of fossils.
3. Make a collection of all the rocks that can be found in your community and try to identify as many as possible. Closely examine them with a magnifying glass.
4. Determine the most common type of rock in the region in which you are living.
5. Visit a museum and examine the rocks, minerals, and fossils that are on exhibition there.
6. Bring to school pieces of stratified and unstratified rock.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is the age of the earth? Man has long wondered about the size, the shape, the age, and the nature of the planet upon which he lives. A study of the literature of primitive peoples shows that their conceptions of the earth were limited. The Hindus imagined the earth borne by a huge elephant standing on a giant tortoise swimming in a sea of milk. The ancient Greeks thought the earth ended at the Pillars of Hercules, and they created many legends and



Courtesy Popular Mechanics Magazine

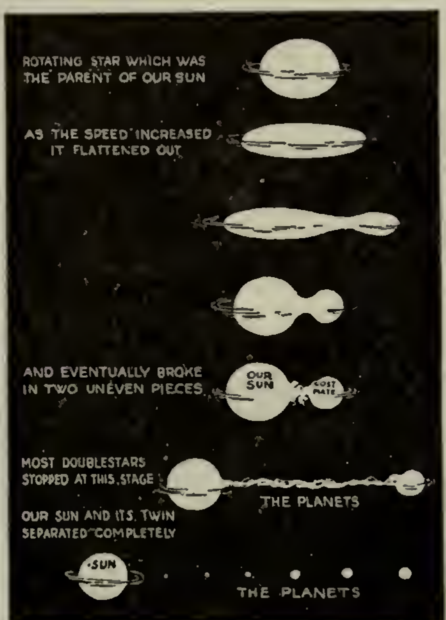
FIG. 317. THE NEBULAR HYPOTHESIS

myths about the relation of the earth to other bodies in the heavens. To those of us who know the facts of the size and shape of our earth these notions of primitive peoples seem highly fanciful and imaginative. Yet we should remember that our early ancestors lacked the tools for obtaining an adequate notion of

[1] See workbook, p. 73.

the earth. They had no telescopes, spectroscopes, or cameras. Airplanes, automobiles, and giant ocean liners had not yet been developed for making long journeys. Today scientists are constantly making observations of the heavens and are studying the rocks, the atmosphere, and the oceans with scientific tools and instruments. As a result much scientific knowledge has been gathered about the history of the earth, its age, and its development, but much work remains to be done.

The exact age of the earth will probably never be known, but from facts gathered by patient scientific work it is certain that our earth is very old. The latest estimates place its age between 2,000 million years and 3,000 million years. It is known that the earth is constantly changing, there being no two seconds when it is exactly the same. These changes seem to take place in an orderly manner, each effect being preceded by a natural cause, thus indicating that law and order prevail. We shall learn a little later about some of the forces constantly at work producing these changes.



Courtesy Science Service

FIG. 318. GUNN'S HYPOTHESIS

How was our earth formed? When the writer was a boy he was taught that the earth and all the other planets were formed from a great hot, rotating mass of gaseous matter that originally occupied the entire space of our solar system. Each planet was thought to have been formed from a gaseous ring that separated from the cooling and shrinking parent mass. The gaseous ring which formed the earth first cooled into a liquid and eventually cooled enough to form a crust of solid rock over a melted interior. This hypothesis, known as the nebular hypothesis, was advanced by Laplace, a great French mathematician and scientist, in 1796 and was believed generally by scientists for more than a century. See Figure 317.

According to the nebular hypothesis:

The earth was once larger than at present.
The earth was once very hot.
The earth became smaller by cooling and contracting.
The atmosphere of the earth was once much heavier than now.
The earth is still cooling.

About the beginning of the present century scientists began to doubt the truth of the nebular hypothesis because many things about our solar system could not be explained by it. Then the *planetesimal hypothesis* was proposed as a better explanation of the formation of our solar system. According to this hypothesis the earth was formed hundreds of millions of years ago as a lump of matter in a spiral nebula. Look at the photograph of a spiral nebula (Fig. 289). Many similar nebulae can be seen in the heavens now with a telescope. Notice that much material is concentrated in the center, and extending outward are curving arms. Dense knots of matter are spaced at intervals along the curving arms. Scattered throughout the arms are smaller knots of matter and countless numbers of tiny particles called *planetesimals*. All the knots and planetesimals move in orbits around the central mass. Collisions occur, causing the larger knots to grow at the expense of the smaller knots and tiny particles.

According to the planetesimal hypothesis the earth at first was much smaller than now. With the passage of time planetesimal matter fell into and collided with the earth, which slowly increased in size. At first it was probably not large enough to hold an atmosphere. But as it slowly grew in size, its gravitational force increased until it was able to hold an atmosphere containing water vapor. As water vapor condensed some of it flowed into depressions in the earth, beginning the formation of oceans.

The growth of the earth is now nearly complete. Some of the brilliant meteors, commonly called "shooting stars," that streak across the sky on a clear night, add slightly to its mass.

According to the planetesimal hypothesis:

The earth was once smaller than at present.
The earth was once colder than at present.
The earth became larger by the addition of planetesimal matter to it.
The temperature of the earth increased as it grew larger because of the heat formed by increased compression.
The atmosphere of the earth was once much lighter than now.

The most recent explanation offered to explain the

formation of our solar system is that suggested by Dr. Ross Gunn of the U. S. Naval Research Laboratory. Dr. Gunn believes that our solar system was formed by the splitting of a large star (see Fig. 318), one part of which became our sun while the other part lost itself in space. According to this new idea certain forces made the star rotate with constantly increasing speed until it burst in two. When the two parts pulled apart, according to the hypothesis, a long stem of matter was formed between them. After a while this matter cooled and gathered into the masses which formed the earth and the other planets.

What is the composition of the earth? The earth consists of three layers of material: first, the atmosphere, a mixture of gases, which forms the outside layer; second, the layer of water that covers approximately three-fourths of the earth's surface; third, the solid earth. There is also an intermingling of these three substances. The atmosphere contains tiny solid particles in the form of dust, and particles of condensed water vapor. The upper crust of the earth contains air and water. You learned many facts about air and water earlier in your study of general science; therefore, we shall confine our attention in this study mainly to the solid earth.

Keystone View Co.

FIG. 319. IGNEOUS ROCKS AT GIANT'S CAUSEWAY, IRELAND

The earth is about 8,000 miles in diameter, but man has been able to penetrate the crust a distance of less than two miles. The solid earth is composed of at least two layers: first, there is a loose outer covering of sand, gravel, clay, and soil called *mantle rock*; below this layer of mantle rock is *bed rock*, which extends to the center of the earth.

The exact nature of the interior of the earth is not known because we are unable to get to it. The earth weighs about 5.5 times as much as a globe of water having the same volume as the earth. This is just another way of saying that the density of the earth is 5.5 times that of water. This is interesting because the average weight of the upper crust of the earth that has been explored is only 2.8 times that of water. Because of this fact it is thought that farther down in the earth there must be heavier materials. When the nebular hypothesis was believed it was thought that the core of the earth was a molten mass. Recent scientific experiments indicate, however, that the center of the earth is as rigid as steel.

What are the main classes of rocks? If you have carefully examined different rocks, you know that they differ from each other in various ways. Some are solid in structure; others are made of separate grains. The particles of which they are composed vary in size, shape, hardness, and chemical composition. Some have their particles or grains in layers; in others the grains are scattered; some are entirely without a granular structure. The nature of a rock depends largely upon how it was formed.

Rocks are generally grouped into three classes: *igneous*, *sedimentary*, and *metamorphic*. Some of the rocks of the earth were once molten. As they cooled they solidified. This happens today when volcanoes pour out their hot molten lava. When the molten matter cools quickly it forms a glassy rock without any crystalline structure. If cooling takes place slowly, crystals are formed, and the slower the cooling the larger the crystals become in size. Examine a piece of granite. It is a good example of a crystalline igneous rock. It is very hard and durable and is widely used as a building stone and for monuments. All rocks

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FIG. 320. STRATIFIED ROCKS AT WATKINS GLEN, NEW YORK

JERRY

solidified from a molten state are classed as igneous rocks.

Rocks which are made of sediment cemented together are called sedimentary rocks. Much of the present land area of the United States was at one time covered by a sea or an ocean. Streams deposited their sediment at the bottom of the sea just as they are doing today. In time these sediments were changed to rock. If a rock consists of particles of sand cemented together it is called *sandstone.* Rocks formed from gravel deposits are called *conglomerates.* Rocks formed from clay are called *shale. Limestone* is also sedimentary rock, believed to have been formed in many cases from the shells and skeletons of ocean animals. Limestone, sandstone, and shale are the leading types of the great group of sedimentary rocks. Try to find a specimen of each type.

Examine several specimens of sedimentary rock to see whether they are marked by parallel lines. Do any of them seem to be made up of thin layers? Is

Keystone View Co.

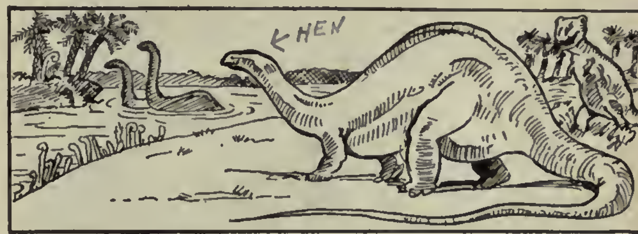
FIG. 321. LIMESTONE ROCKS AT MAMMOTH CAVE, KENTUCKY

each layer spread evenly over another? Rocks of this type are called *stratified.* Each layer is known as a stratum (plural, *strata*). Stratification can be seen very well in soft coal, a sedimentary rock made from vegetable matter.

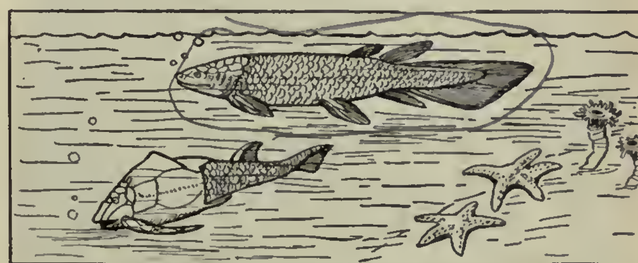
Sedimentary or igneous rocks that have been changed by the combined activities of heat, pressure,

METAMORPHIC ROCK	FORMED FROM
Marble	Limestone
Quartzite	Sandstone
Slate	Shale
Gneiss	Conglomerate or granite

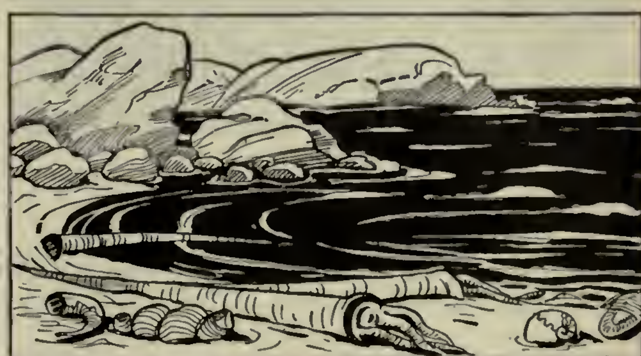
ANIMALS THAT LIVED 25,000,000 YEARS AGO



ANIMALS THAT LIVED 200,000,000 YEARS AGO



ANIMALS THAT LIVED 400,000,000 YEARS AGO



ANIMALS THAT LIVED 550,000,000 YEARS AGO

FIG. 322. ANCIENT LIFE AS RECONSTRUCTED FROM FOSSILS

and chemical action become metamorphic rocks. Marble is a metamorphic rock formed from limestone, a sedimentary rock. Slate is a metamorphic rock formed from shale. Gneiss (nīs) is a metamorphic rock formed either from granite, an igneous rock, or from conglomerate, a sedimentary rock.

Metamorphic rocks resemble igneous rocks in that they frequently have a crystalline structure. Many

metamorphic rocks are also banded, tending to split into layers; in this quality they resemble sedimentary rocks. The table on page 199 names a few metamorphic rocks and the rocks from which they were formed. Try to find specimens of each and examine them.

What are fossils? One of the most interesting things about the earth is the life upon it. So far as we know there is no other heavenly body that possesses living inhabitants. It is true that Venus and Mars seem in some ways possible abodes of some forms of life, but whether they actually do have any life upon them is a matter of speculation.

Courtesy American Museum of Natural History

FIG. 323. A FOSSIL FERN

Today our earth teems with life. Hundreds of thousands of different plants and animals inhabit the air, land, and water. When, where, and how did life get started on our earth? These are questions which scientists are not yet able to answer entirely.

Scientists believe that the earth is at least two billion years old. They also believe that there was a time when the earth was without life and that the first forms of life that appeared on the earth were simple, lower forms. What is the foundation for these beliefs? Fortunately many of the ancient forms of life have left records for us to read. They have done this in several ways.

In rocks we often find evidence of life of the kind that existed when the rock was being formed. We find imprints or the remains of plants and animals. Sometimes we find a part of an animal; for example, shells and bones. Limestone rock often shows traces of shells of which it is chiefly composed. Sometimes the plant or animal was buried in sediment and there slowly dissolved. Little by little, mineral matter would take the place of the flesh and bone until finally there would seem to be an animal or plant made of stone. Remains of plant life in the form of impressions of leaves, stems, or petrified tree trunks are found. It is not unusual to find the imprint of an ancient fern whose shape shows on a piece of coal that it helped to form. All these remains of ancient plants and animals, including petrified forms and imprints, are called *fossils*.

In some parts of the world where it is always cold, especially in Siberia, the frozen bodies of ancient animals have been found. Chief among these is the *mammoth*, which was somewhat like an elephant, but more hairy. Being covered with snow and ice, it was protected from flesh-eating animals, and the temperature was low enough to keep it from decaying.

Many small animals such as insects have been found in amber. Amber is a hardened resin which came from certain trees. Some of the animals found preserved in resin are nowhere on the earth today.

Near Los Angeles are tar pits, places where a heavy, sticky liquid appears at the surface of the earth. From these pits have been recovered bones of animals that must have lost their lives a long time ago,

Courtesy American Museum of Natural History

FIG. 324. A FOSSIL SHELL

for some of them are not now found alive anywhere on the earth.

From a study of rocks and fossils the following conclusions have been drawn.

1. Living things have been on the earth a long time, perhaps more than five hundred million years.

2. Simple living things such as one-celled plants and animals came into existence first.

3. Life on the earth has been slowly changing. As time goes on many forms of life die out and are replaced by more and more complex forms.

Exercise. *In your notebook*[1] *make a list of facts to support each of the following general statements.*

The earth is very old.

Scientists are not sure just how the earth was formed.

The earth has not always been as it is today.

Scientists understand how the various types of rocks were formed.

Scientists are able to tell with considerably accuracy the kinds of climate prevalent during past ages of the earth.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science far Today*, Chap. 19

Clement, Collister, and Thurston, *Our Surraundings*, Chap. 21

Hunter and Whitman, *My Own Science Problems*, Unit 9; *Science in Our Sacial Life*, Unit 10

Lake, Harley, and Welton, *Exploring the Warld af Science*, Chap. 13

Pieper and Beauchamp, *Everyday Problems in Science*, Unit 2

Powers, Neuner, and Bruner, *This Changing World*, Chaps. 16, 17; *Man's Cantral of His Enviranment*, Chap. 32

Skilling, *Tours through the Warld af Science*, Tours 1, 2

Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 7

Watkins and Bedell, *General Science for Today*, Unit 3

Webb and Beauchamp, *Science by Observation and Experiment*, Unit 7 (part)

Wood and Carpenter, *Our Enviranment: Its Relation to Us*, Topic 4; *Our Enviranment: How We Control It*, Topic 13

[1]Set workbook, p. 74.

Special references

Fabre, *This Earth of Ours*

Grew, *The Romance of Madern Gealagy*

Hawksworth, *The Strange Adventures of a Pebble*

Loomis, *Field Boak of Cammon Rocks and Minerals*

Lucas, *Animals of the Past*

Thomson, *Outline of Science*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The concept that the earth is very old.
2. A knowledge of the various classes of rocks and how they are formed.
3. Skill in identifying common rocks and minerals.
4. The habit of observing the nature and types of rock in your community.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Marble is a ____ rock.
2. Limestone is a ____ rock.
3. Granite is a ____ rock.
4. How are igneous rocks formed?
5. How were metamorphic rocks formed?
6. How were stratified rocks formed?

Select the word or group of words which most satisfactorily completes each of the following statements.

7. Rocks formed of sediment deposited by water are called
   metamorphic igneous sedimentary marble conglomerate
8. Rocks formed by heat and pressure are called
   igneous sedimentary conglomerate metamorphic limestone
9. Rocks formed from hot molten matter are called
   conglomerate metamorphic igneous limestone sedimentary
10. An example of a sedimentary rock is
   limestone granite marble quartz slate
11. Which of the following is a metamorphic rock?
   granite marble limestone quartz
12. Which of the following is an igneous rock?
   granite shale coal marble limestone
13. The remains or imprint of a living thing in rock is called mineral erosion fossil humus shale
14. The age of the earth is believed to be
   billions of years millions of years thousands of years hundreds of years

TOPIC 2. THE WEARING AWAY OF THE EARTH'S SURFACE

SUGGESTED PROBLEMS AND QUESTIONS

1. What are the agents of mechanical weathering?
2. What are the agents of chemical weathering?
3. What are the agents of erosion?
4. What are the dangers of too much erosion?
5. What internal agencies change the earth's surface?

SUGGESTIONS AND HELPS FOR STUDY

1. Read the problems carefully and be certain that you understand them before you begin your reading and investigations.

2. In working out the problems, make a careful study of each of the following: ice, wind, water, temperature changes, plants, animals.

3. Make personal observations and study of a region which is not being eroded very much, and contrast it with a region which is being eroded rapidly.

In this way you may be able to determine some of the factors that help prevent erosion.

4. Read the available reference materials and make a list of the advantages of weathering and erosion. Make another list of their disadvantages.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 126. Why are streams yellow after heavy rains?

After a heavy rain, fill a two-quart jar with the yellow water from a stream. Let it stand undisturbed for several days. Record your findings in your notebook.

Where did the sediment that was in the water come from? Running water is an agent of ____.

Experiment 127. How do changes in temperature help to break up rock?

Heat a piece of glass. Plunge it into cold water. What happened? Might rocks be crumbled in this way? Explain.

Fill a bottle with water. Insert the stopper and tie it securely with a string. Pack the bottle in a mixture of ice and salt. Examine later. What happened?

Does the freezing of water break rock?

Activity 128. What evidences of erosion can you find after a heavy rain?

After a heavy rain take a trip to a country district and observe the many evidences of the work of running water. Keep a record of your observations and report them to class.

Try to find evidences of the work of plants and animals in breaking up rocks and soil. If glaciers have crossed the region in which you are living, try to find some of the effects. Perhaps you can find scratches on exposed rock beds or transported boulders. Record your observations.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

The surface of the earth is ever changing. One of the great truths of science is that the earth's surface is constantly undergoing change. As we travel across the earth's surface we are impressed by the variety of conditions that we find. Great oceans, high mountains, hills, valleys, rivers, plains, plateaus, deserts, and lakes attract our attention. Have you ever wondered how the earth came to be as it is today? Have you ever wondered whether it was the same in past ages or what changes we may expect in the future? Scientists are at work trying to find answers to these very questions, and they have much knowledge to impart to you if you will but read, study, and think.

Great contending forces are at work constantly changing the surface of the earth. Some of these agencies like rivers, wind, freezing water, and changes of temperature wear down the high places and tend to fill the low places. The processes by which rocks are broken down are called *weathering* and *erosion*. In addition to weathering and erosion, great forces are at work within the earth that elevate parts of the earth's crust. The present surface features of the earth are the result of all these forces. You will learn more about these things as you study this unit of work.

What are the agents of mechanical weathering? Weathering is produced by changes of temperature, by ice, by plants and animals, and by the force of gravity.

Temperature changes affect rocks. Have you performed the experiment of heating a piece of glass and plunging it into cold water? Did the glass crack? Temperature may vary more than fifty degrees Fahrenheit between the heat of day and the cold of night. During the day the rocks become strongly heated by the rays of the sun and expand. At night they cool rapidly and

Courtesy American Museum of Natural History

FIG. 325. PIECES OF ROCK BEING PUSHED APART BY GROWING TREE

Keystone View Co.

FIG. 326. A STUDY OF EROSION

The effects of running water and of wind as agents of erosion are apparent; the work of vegetation to prevent erosion may be seen in the right foreground.

[1] See workbook, p. 74.

contract. Rocks are poor conductors of heat. Their surfaces become very hot during the day while the interior of the rock remains cool. The differences in the amount of expansion and contraction between the surface and the interior of a rock produce strains that frequently cause it to break.

William Thompson

FIG. 327. A MOUNTAIN GLACIER IN NORWAY

Freezing water helps to break rocks. Have you ever seen water pipes that burst after water had frozen in them? If you have, you know that water, as it changes from a liquid to a solid, expands and exerts tremendous pressure. All rocks are more or less porous, and they sometimes have cracks in them. Water seeps into these places, freezes, and cracks the rock.

Plants and animals change the earth's surface. The roots of herbs and trees growing in crevices exert pressure and slowly wedge rocks apart. The roots of plants also give off weak acids which may combine chemically with rocks and weaken their structure. The decay of plants results in the formation of certain acids that attack rocks and help to change them into soil.

Although animals are not so destructive as plants, they do assist in changing rock to soil. This work is done mainly by animals such as moles, gophers, ants, and worms that live or move about in the ground. They turn over the soil and expose new surfaces to other agencies of weathering. Man must also be mentioned because his digging in the earth and his destruction of forests have resulted in many areas of the earth being weathered and eroded after he has removed their natural protection.

Gravity affects the earth's surface. The force of gravity may pull pieces of rock to the earth. This happens frequently on cliffs of rock that have been exposed to other agencies of weathering. The falling fragments of rock break up other rock, exposing new surfaces to other agencies of weathering.

What are the agents of chemical weathering? The mechanical breaking up of rock is greatly aided by certain chemical processes.

Chemical work of water. We have already learned that water is a good solvent. Water absorbs carbon dioxide from the air and as it sinks into the earth dissolves acids that were formed by plants. Charged with these active chemical substances it reacts chemically with rocks and decomposes them.

Chemical action of the air. Oxygen, carbon dioxide, and water vapor in the air react chemically with substances in many rocks and greatly weaken their structure.

What are the agents of erosion? The agencies of weathering slowly change rock into soil. If it were not for erosion, weathering would gradually cease as the underlying bed rock became sufficiently protected by a covering of weathered materials. Generally, however, agents of erosion carry away the weathered materials and expose fresh surfaces to attack.

The work of ground water. When moisture condenses in the air and falls to the earth as rain or snow, some of it evaporates, returning to the atmosphere; some of it flows over the surface of the earth in streams; and the remainder soaks into the ground. That which sinks into the earth is called *ground water.* Ground water in its journey underground dissolves parts of the rocks and soils through which it seeps. These dissolved substances are carried to streams which finally empty into seas and lakes. Carbon dioxide of the air unites with water to form a weak acid (carbonic acid) that dissolves some rocks. Water containing carbon dioxide is especially active on limestone rock and is responsible for the famous Mammoth Cave (Fig. 321) and the caves found in other limestone regions of the United States.

The work of running water. Rainfall and melting snow gather into streams and slowly wear away

mountains and hills, transporting dissolved materials and sediments to the sea. Much of the material that a stream carries is supplied by the weathering of its valley slopes. Some of its load is secured by eroding away its beds and banks. Erosion by streams is carried on chiefly by means of the sand, stones, pebbles, and fine mud they sweep along. These materials moved along by the stream grind, scrape, and scour the river bed and banks, acting much the same as a file or a piece of sandpaper.

Courtesy Popular Science Monthly

FIG. 328. GLACIAL MAP

White shading shows extent to which ice covered North America in The Ice Age.

Work of the wind. On windy days, especially in dry weather, bits of dust and sand are raised from the earth and carried along by the strong air currents. The presence of these solid particles in the air increases its erosive power. In arid regions of the world where vegetation is scarce, wind plays an important part in soil making. In regions with moist climates the earth is generally protected by a covering of leaves, stems, and roots of plants.

Work of glaciers. When more snow falls in a region than melts, the snow slowly accumulates. As the mass of snow becomes thicker and thicker it is changed into ice, forming a *glacier*. A glacier moves slowly down its slope, seldom exceeding a few feet a day. Glaciers erode, transport, and deposit materials, but the manner in which the work is done and the results achieved are different from the action of rivers. As the glacier moves along, earth and stones are frozen fast to its bottom and sides. These scour and grind away the bed rock and the sides of the glacier valley.

At the present time glaciers are confined to the polar regions of the earth and high mountains such as the Alps in Europe and the Rockies in North America. It is believed, however, that thousands of years ago, at least four different times, great ice sheets moved down from the north and covered Canada and a large part of the United States, as far south as the Ohio and Missouri rivers (see Fig. 328). As these glaciers receded, or melted back, they deposited their materials.

FIG. 329. ROCK SHOWING GLACIAL SCRATCHES

Glacial deposits are easily distinguished from sediments deposited by rivers. They are unassorted; great boulders, stones, pebbles, and clay are all mixed together, whereas sedimentary deposits by rivers are stratified. Stones and pebbles in glacial deposits are not generally as round and smooth as pebbles carried by streams. Glacial erosion often leaves bed rock marked with scratches and grooves made by pebbles and sand held firmly in the frozen ice (see Fig. 329).

If you are living in a region over which a glacier passed, make a field trip and observe evidences of glacial erosion. Report your findings to your class.

The work of tides, waves, and currents. The sea is ever restless. Storm waves strike the ocean shore with tremendous force. Tides and shore currents are constantly beating on the coast. Sea water helps to disintegrate some kinds of rock by its solvent action on them. Other mechanical agencies break off pieces of rock. These fall into the sea and are then driven violently by the impact of the waves against the rocky shore. The combined action of these forces slowly grinds back the shore, depositing the weathered and eroded substances in the sea.

What are the dangers of too much erosion? Con-

siderable amounts of the valuable top soils of our country are moved away by the influence of running water and wind. During the past years much land

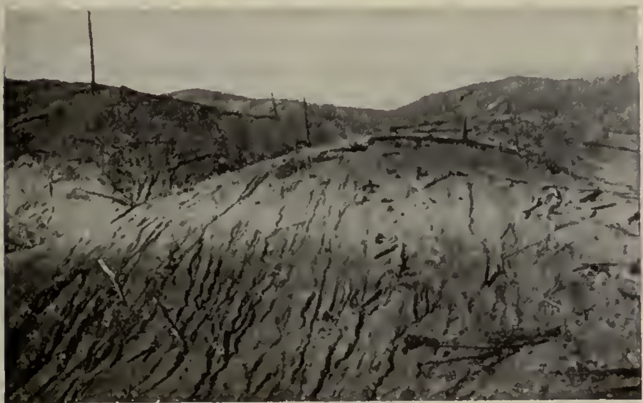


Photo by U. S. Forest Service

FIG. 330. EROSION TAKES PLACE WHERE FORESTS ARE REMOVED

that had been used for farming has become furrowed and gullied waste land. See Figure 330. Perhaps you have been reading about the devastating dust storms in the Midwest which are making it difficult for farmers to cultivate what was once fertile soil. Soil erosion is natural and is to be expected in the ordinary course of events; but the rapid transfer of soil, characteristic of recent years, has created a national problem. Part of the solution of this important problem lies in main-

International News Photos

FIG. 331. LAVA DEPOSITS IN ARGENTINA

taining our forests and in maintaining other vegetation on the soil which will help to prevent valuable top soil from being carried away by wind and running water.

What internal agencies change the earth's surface? With the exception of the work of underground water, the work of the various agencies thus far considered is confined to or near the surface of the earth. We shall now consider several agencies at work within the earth.

Volcanoes. Not long ago men believed that the greater portion of the earth consisted of a molten mass covered by a hard crust. Volcanoes were looked upon as "safety valves" for this interior of heated liquid. Recent scientific experiments indicate, however, that the interior of the earth is rigid like steel, making it necessary to find another explanation for volcanoes.

At present it is thought that as the earth slowly increased in size, the force of gravity also increased, resulting in greater internal pressure. This pressure produced more heat and a rising internal temperature. Eventually enough heat was produced to melt some of the more easily melted materials, thereby forming pockets of molten matter at various places, perhaps not many miles below the surface of the earth. This molten matter moved slowly toward the surface of the earth, but the manner in which this ascending movement takes place is not exactly known. Since most volcanoes are located in regions of the earth where movements and disturbances are taking place, it is believed that zones of weakness in the crust of the earth have afforded favorable places for molten matter to move upward to the surface. There are still many unsolved problems about volcanoes; our present beliefs are based partly on observed facts and partly on the planetesimal hypothesis.

Today there are only about three hundred active volcanoes, but in past ages much more volcanic activity took place. Molten matter that formed solid rock was spread over many places on the earth's surface. Sometimes large quantities of molten matter were forced through crevices and weak places in the earth's crust and solidified before they reached the surface. Volcanic eruptions sent out showers of ashes, cinders, gases, and lava, and in some cases whole cities have been completely buried and destroyed. An eruption of Mt. Vesuvius near Naples, Italy, in A.D. 79 completely covered the cities of Pompeii and Herculaneum. The city of Pompeii was rediscovered in 1748, and since then its covering of ash has been removed by careful digging and excavating.

The earth's crust undergoes warping and twisting. As a result some regions of the earth are elevated while other places are caused to sink. The rocks of some hills and mountains were laid down as soft mud on ocean bottoms, yet today they are thousands of feet above sea level. One naturally wishes to know what happened to bring these rocks above the sea. We can-

William Thompson

FIG. 332. CRACK OR FISSURE PRODUCED BY EARTHQUAKE

not state exactly the nature of all the forces at work producing these changes. It is believed that heavier materials move toward the center of the earth and push lighter materials upward. Materials under the oceans are slightly heavier than those of land areas. The difference in pressure would tend to elevate the continents and deepen the oceans. The fact that some mountain systems, such as the Rockies and the Appalachians in North America, are near the coast line tends to support this belief.

Earthquakes. Sometimes movements of the earth's crust are accompanied by sudden slipping of rock. Vibrations are then set up that travel through the earth. These vibrations are called *earthquakes.* Generally these vibrations produce only a slight trembling of the earth, but occasionally the vibratory motion is so intense as to cause buildings to tumble down. An entire city may be wrecked in a few minutes.

Earthquakes are recorded and studied by means of an instrument called a *seismograph.* This instrument consists of a pendulum (a heavy weight hung on a wire) with a pointer on the end of it that hangs motionless except when the earth is vibrating. The instrument is very sensitive, and during the tremors of an earthquake the pointer swings back and forth, making sharp lines on a piece of paper covered with lamp black. The smoked paper is on a rotating drum that is turned automatically by a clock, making it possible to tell from the marks left on the paper the exact time of day the earthquake took place.

Exercise. *From your study, cite evidence in support of each of the following general statements.*[1]

1. *The surface of the earth is ever changing.*

2. *Forces tending to wear away the earth's surface are at work.*

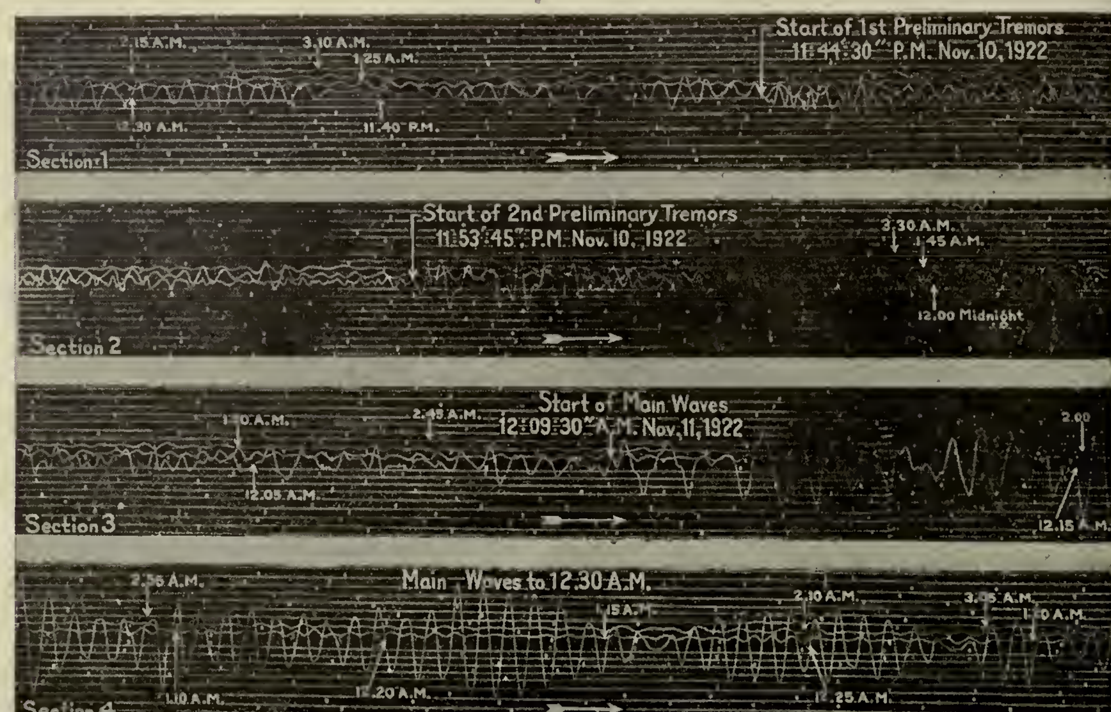
3. *Scientists have learned some facts about the internal structure of the earth.*

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 19
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 21
Hunter and Whitman, *My Own Science Problems,* Unit 9; *Science in Our Social Life,* Unit 10
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 13

[1] See workbook, p. 75.



Courtesy American Museum of Natural History

FIG. 333. SEISMOGRAPH RECORD OF AN EARTHQUAKE IN CHILE

Pieper and Beauchamp, *Everyday Problems in Science,* Unit 2
Powers, Neuner, and Bruner, *This Changing World,* Chap. 15; *Man's Control of His Environment,* Chap. 4.
Skilling, *Tours through the World of Science,* Tours 1, 2
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 7
Watkins and Bedell, *General Science for Today,* Unit 3
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 7 (part)
Wood and Carpenter, *Our Environment: Its Relation to Us,* Topic 4; *Our Environment: How We Use and Control It,* Topic 13

Special references

Loomis, *Field Book of Common Rocks and Minerals*
Hawksworth, *Strange Adventures of a Pebble*
Fabre, *This Earth of Ours*
Small, *The Boys' Book of the Earth*
Washburne, *The Story of the Earth*
Fall, *Science for Beginners*
Grew, *The Romance of Modern Geology*
Reed, *The Earth for Sam*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Understand thoroughly the work of the various agencies of erosion.
2. Know the importance and means of protecting fertile places from being eroded.
3. Develop a scientific attitude toward the preservation of certain forest lands as a means of preventing floods and excess erosion.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Running water causes ____.
2. Plants change ____ into soil by growing in ____ of the rock.
3. Water erodes rock in two ways: by ____ it and by ____ it.
4. When water falls to the earth from the clouds what three things may happen to it?
5. When water freezes it ____ and helps to ____ rocks.
6. Heating causes rocks to ____ while cooling causes them to ____.

Select the word or group of words which most satisfactorily completes each of the following statements.

7. The wearing away of rocks or soil is called
   conservation irrigation cultivation erosion sedimentation
8. Water is an agent of erosion when it
   evaporates boils contracts freezes condenses
9. The most common cause of erosion in desert regions is
   wind sun plants dryness extreme temperature
10. Glaciers consist largely of
    rocks vegetation ice sediments streams
11. Soil is protected from erosion by
    irrigation vegetation reclamation animals wind

TOPIC 3. THE IMPORTANCE OF SOIL

SUGGESTED PROBLEMS AND QUESTIONS

1. How are soils formed?
2. What are the different kinds of soil?
3. Upon what factors does crop raising depend?
4. How are waste lands sometimes reclaimed by irrigation and drainage?
5. How is soil fertility maintained?

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully read and study the problems listed above.

2. Proceed to the study of the problems, securing material from your textbooks and other reference works.

3. Much of your knowledge of this topic will have to be obtained from books. However, a number of texts listed for reference in this topic suggest some interesting experiments for certain phases of the work. Do as many of these as you can.

4. If you are living in or near a rural community you may be able to find materials for many of the problems by personal observation and investigation.

5. Study the definitions of the following words.

legume—a plant such as the pea or bean, bearing pods.
nodules—thickened knots or lumps on roots of legumes.
humus—decayed vegetable matter.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 129. What are the different kinds of soil?

Collect samples of soil from different places (field, hillside, pasture, woods, etc.). Keep the samples tightly closed in a tin can or jar until you are ready to examine them. After you have examined them carefully, make a table in your notebook and record facts about the samples. In the table, use these headings: source of soil, coarse or fine, color, dry or moist, amount of humus.

Experiment 130. What enables water to rise in soils?

Obtain some capillary (hair-like) tubes of different diameters. Arrange them in a dish from the largest to the smallest diameter as shown in Figure 334. Pour water, colored with ink, into the dish until the water level is above the

[1] See workbook, p. 75.

bottom of the capillary tubes. Observe what happens. Hold one end of a cube of sugar in the colored water. Suspend one end of a piece of blotting paper in the colored water. Record your observations.

Water rises in tubes and porous materials by capillary attraction.

Obtain five tall lamp chimneys. Tie a layer of cloth over the top of each chimney (see Fig. 335). Set the chimneys in a shallow dish. Pour clay into the first chimney, fine sand

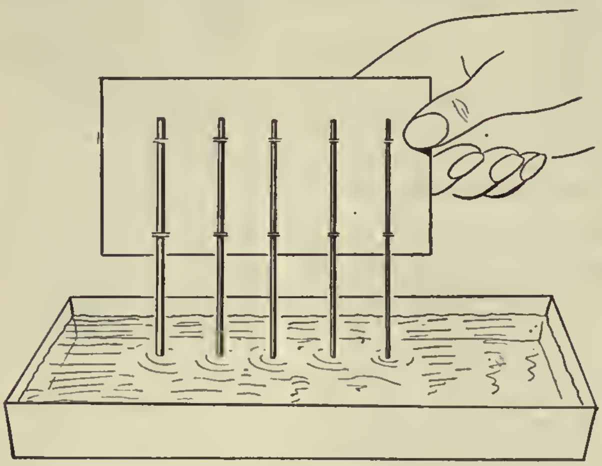


FIG. 334

into the second, loam (a mixture of sand and clay) into the third, coarse sand into the fourth, and gravel into the fifth. Fill each chimney about three-fourths full. Pour water into the shallow dish and observe how high the water rises in the various types of soil. In your notebook, record your observations and answer the following questions. Why does water rise in soil? Why does a farmer go through his fields with a cultivator to break up the soil?

Experiment 131. How rapidly does water sink in soils?

Use the same lamp chimneys for this experiment as were used in the last experiment. Fill the chimneys with fresh samples of the various soils. Hold each chimney over a quart jar and slowly pour into each a pint of water. How much water passed through each type of soil and how long did it take? Record your results. List the soils in the order of their ability to hold water.

Activity 132. How are soils kept fertile?

Interview some farmers in your locality and find the methods employed for keeping the soil fertile. Also go to stores that sell fertilizers and get the names of the fertilizers sold. Find out what chemical elements are present in these fertilizers. Keep a record of your findings and report them to the class.

Experiment 133. How do plants of the legume family help fertilize soil?

Locate a clover, alfalfa, or pea plant. Carefully remove the plant with its roots. Soak the roots in water and carefully wash away the dirt. Notice the little nodules attached to the roots. Explain the work they do and their importance.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Living things are dependent upon soil for their existence. Most plants obtain water and minerals directly from the soil. Animals live on plants; therefore, the food elements which nourish their bodies come originally from the soil.

For untold ages man was a food gatherer. Human population was small and food was very plentiful. Wild animals, fish, edible plants, seeds, roots, and berries he could easily gather to meet his needs. Eventually because of the increase in population it became necessary for man to plan for his food supply. This led to the development of agriculture.

For several thousands of years agriculture has been one of man's basic industries. Agriculture furnishes us our food materials and many raw materials for manufacturing industries. Our present mode of living would be impossible without the foods produced by farming. Man is constantly occupied with the problems of maintaining fertility of old soil and of finding new fertile soils.

As we proceed with this topic we shall learn about soil and the factors which must be controlled in order to carry on agriculture successfully.

How are soils formed? You learned in the previous topic how agencies of weathering and erosion change bed rock into smaller particles. Soil in any particular

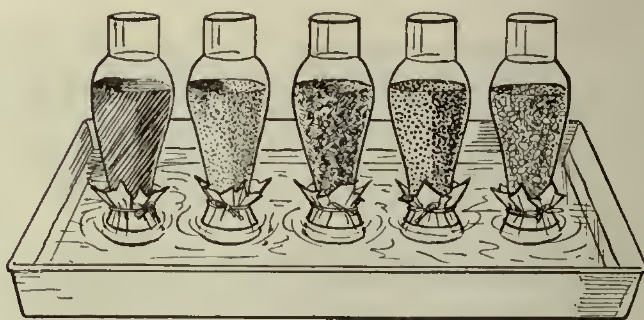


FIG. 335

locality may be formed in two ways. First, the soil may have been formed by weathering from the rocks beneath it, in which case it is composed of the same substances as the rocks below. Soils formed in this way are called *residual* soils. Second, the soil may have been brought there from a distance. Soils formed in this manner are called *transported* soil. Soils formed of deposits by streams, glaciers, and wind belong to this class. Transported soils generally are composed of a richer variety of materials and are preferred to residual soils for crop raising.

Particles of rock alone do not make a fertile soil.

The rock materials must also contain *humus* (decayed vegetable matter). Soils may be made fertile in the following manner. Lichens and some other low forms of plant life are the first to establish themselves on infertile rocks and rock particles, as they need almost no soil to live. They die and leave small amounts of minerals and humus from which mosses can gain enough nourishment to grow. The soil is further enriched as the mosses die, and later ferns and grasses appear. This process goes on for centuries, and as the fertility of the soil increases, higher and higher forms of plant life become established. Leaves, stems, and roots from shrubs and trees decay and add still more humus to the soil. Thus we see that our natural fertile soils are formed from particles of rock that supply the mineral matter and from decayed plants that supply humus.

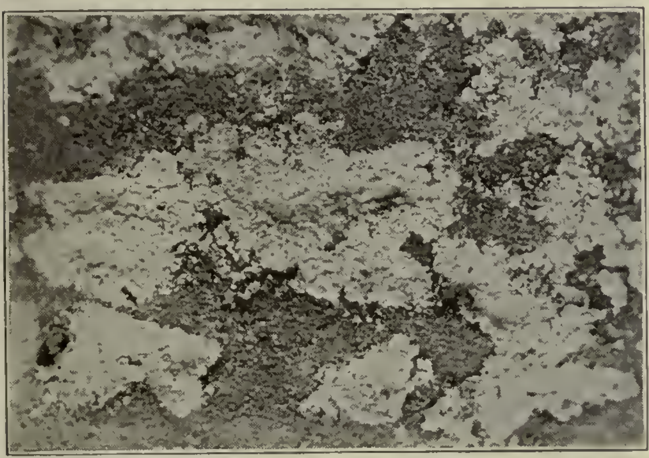


Photo by C. K. Sibley

FIG. 336. LICHENS GROWING ON A ROCK

What are the different kinds of soil? If you examined samples of soil, as suggested in one of the experiments, you perhaps noticed that they consisted of particles of different sizes. Soils are classified according to their sizes into four principal types: *gravel, sand, silt,* and *clay*. The following table gives a classification of soils based on the size of particles.

KIND OF SOIL	SIZE OF PARTICLES
Gravel	Over 1/50 inch in diameter
Sand	1/50 to 1/500 inch in diameter
Silt	1/500 to 1/5000 inch in diameter
Clay	Smaller than 1/5000 inch in diameter

Soils also contain varying amounts of humus. The larger the amount of humus in soils, the less the soils weigh. For this reason humus soils are spoken of as light soils.

Underwood

FIG. 337. VEGETATION IN AN EXCESSIVELY MOIST REGION

Plants do not grow well on soils made up of particles of only one size. A clay bank or a sandbar could not be profitably cultivated. Soils most useful for farm and garden crops consist of mixtures of sand, clay, and humus. A nearly equal mixture of clay and sand is called *loam*. Soils containing more clay than sand are called *clay loams* while those in which sand predominates are called *sandy loams*.

Upon what factors does crop raising depend? Crop raising depends on a number of important factors such as temperature, rainfall, sunshine, and soil fertility. Man cannot control the weather, but he can do much toward providing the proper soil conditions necessary for good plant growth. These include proper conditions of moisture, air, temperature, and soil fertility. Let us consider now some of the problems involved in maintaining a proper supply of moisture.

Soil water. All soils contain water, but the amount in different soils varies greatly. Plants also vary greatly in the amount of water they need to flourish. The cactus can thrive where there is little moisture, whereas the willow is commonly found where there is a large supply. As a rule, our common garden plants do not grow well in extremely wet or extremely dry soils. Every one has observed crops dying in a swampy place and also in a time of drought.

How does water rise in soils? Water moves through soil by means of capillary action. Soil particles form irregular tubes much as in the case of a sugar lump or blotting paper. The fine tubes are called *capillary tubes*. They provide passageways for the deep soil water to reach the plant roots and the surface of the ground. The water goes not only upward in these tubes but in any direction in which they may lead. The amount of water and the distance that water rises in soils by capillary action depends upon the size of the spaces and the fineness of the soil particles. The finer the soil, the smaller the tubes. Thus the distance traveled

through coarse sand is much less than in fine sand or clay.

The chemical elements which plants need are dissolved in very small amounts in soil water and enter the plant with the soil water which is taken in by the roots of plants. It is necessary that large amounts of water be available for plants. Much of this water is evaporated from the leaves of plants into the atmosphere while the elements dissolved in the water remain in the plant. Also a large amount of soil water rises to the surface of the ground and is evaporated directly from the soil into the atmosphere. This means that as much as possible of the water which gets into the soil must be conserved.

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FIG. 338. VEGETATION OF A DESERT

Evaporation of soil water may be reduced to a minimum in several ways. The one most commonly used by farmers and gardeners is *cultivation.* This is done, in part, to prevent the growth of weeds, but more important still, it is done to conserve soil water. If the surface layer of the soil becomes hard, capillary action causes water to rise to the surface, where it is evaporated and lost to plants. However, if the soil is well cultivated, capillary tubes near the surface are broken up. Cultivation also loosens the surface soil and provides a good circulation of air around the roots of plants. The prevention of evaporation of soil water is sometimes accomplished by *mulching.* In this process the farmer spreads a layer of hay, straw, or leaves around the plants and between the rows. This surface covering retards the evaporation of capillary water.

Photos by Bureau of Reclamation, Department of Interior. Courtesy Scientific American.

FIG. 339. IRRIGATION PROJECTS

Above—Boise River diversion dam, power plant, and intake to irrigation canal

Below—Irrigating from concrete-lined ditches

In some arid regions of the country the average rainfall is sufficient only to grow a crop once in two years. In these places it is common for the farmers to continue cultivation during the period in which no crop is grown. This tends to accumulate and conserve

the soil moisture so that there will be enough water for a crop the following year. This is called *dry farming.* Dry farming does not mean that crops are made to grow without water, but only that whatever water falls is carefully conserved.

Soil temperature is another factor in plant growth. Seeds develop faster and plants grow more rapidly when the temperature is between 65 and 75 degrees Fahrenheit. We have seen that cultivation retards the evaporation of soil water, and this in turn reduces the

Keystone-Underwood
FIG. 340. DIGGING DITCHES TO RECLAIM SWAMPY LANDS AND TO DESTROY MOSQUITOES

amount of cooling which always accompanies evaporation. Thus in the one process of cultivation three essential factors in soil conditioning may be provided for: the conservation of soil moisture, the conservation of soil temperature, and the proper circulation of air around the roots.

How are waste lands sometimes reclaimed by irrigation and drainage? Desert waste lands in regions of the United States have been transformed into fertile farms and gardens by supplying water artificially to the soil. This process is called *irrigation.* Soils that are irrigated successfully possess naturally the proper minerals and humus for crop raising, but they do not receive enough rainfall for plants to grow. In some regions to make up for deficient rainfall great reservoirs have been built by damming a valley with enormous cement walls. These reservoirs hold the water of the rainy season for use during the dry season. As the farmers need water it is delivered to them through irrigation canals. Already large areas of arid and semi-arid lands in Arizona, California, Colorado, Texas, and other states have been reclaimed for farms, gardens, and orchards.

In other regions of the United States there are fertile lands that receive an excess of water. This condition is corrected by constructing an *artificial drainage system.* Care must be taken, when artificial drainage is employed, to see that sufficient water is left in the soil for the proper growing of plants.

How is soil fertility maintained? As plants grow they take certain elements from the soil. Scientists have determined that the following ten chemical elements are the essential elements of plant food and

From A Textbook of General Botany *by Smith and Overton. By permission of the Macmillan Company, publishers.*

FIG. 341. PLANTS OF THE SAME SPECIES, SHOWING EFFECTS ON GROWTH OF THE OMISSION OF DIFFERENT ELEMENTS

that with the exception of some carbon and oxygen they are obtained directly from the soil:

carbon	potassium
hydrogen	phosphorus
oxygen	sulphur
nitrogen	magnesium
calcium	iron

From the standpoint of soil fertility, phosphorus, potassium, nitrogen, and calcium are the most important elements to be considered. The other elements are present in sufficient quantity in most soils. Plants, however, vary in the amounts of phosphorus, potassium, nitrogen, and calcium they need for healthy growth. Corn, for example, removes all of these elements, whereas wheat uses more of the phosphorus. The important thing to remember is that crop raising reduces soil fertility and that any soil will eventually become infertile unless the elements removed from it by growing plants are again restored. It is for this reason that successful farmers artificially fertilize their soil.

In walking through a wood or a forest, have you

noticed nature's way of maintaining soil fertility? On the ground are rotting leaves, branches, and limbs of trees. These decaying plant remains add humus to the soil and restore minerals taken from it by the growing vegetation. Successful farmers imitate nature's method by adding manure to the soil. If green plants are plowed under, they are called *green manure.* Sometimes farmers grow cowpeas, rye, or clover after the harvesting season and then plow them under before the next planting season. The plants decay and add humus and nitrogen to the soil. Farmers also scatter the manure from animals over their fields. This is one of the oldest and most practicable methods of maintaining soil fertility. Manure is more desirable than commercial fertilizers because it adds humus to soil at the same time that it enriches it with important chemical elements.

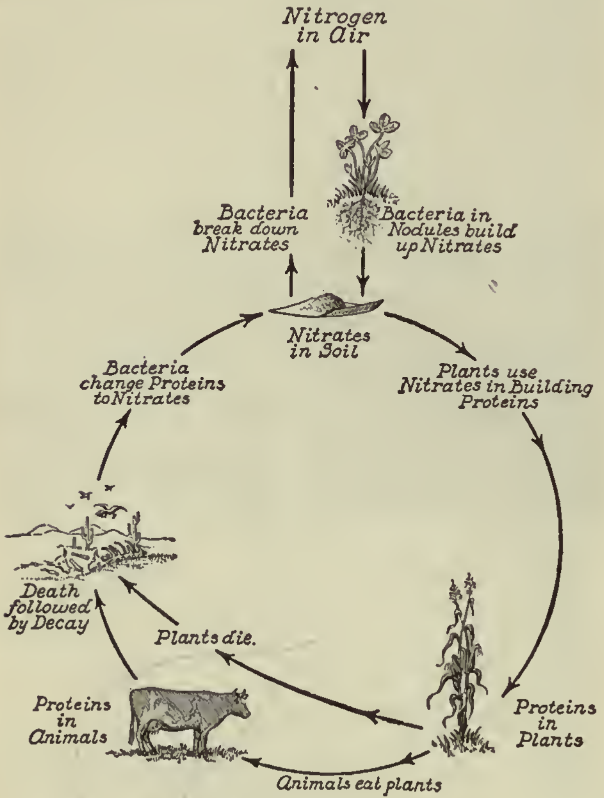


FIG. 342. NITROGEN CYCLE

All plants and animals require nitrogen. In our study of foods we learned that nitrogen occurs in substances called proteins.

Plants build up proteins from water, carbon dioxide, and the chemical elements they obtain from the soil. Animals obtain their proteins from plants or animals they eat. The waste products of plants and animals and their dead bodies return to the soil. Here the proteins they contain are broken down by soil bacteria into simpler nitrogen compounds. These simpler substances dissolve in soil water and are absorbed and used again by other plants (study Fig. 342). Thus nitrogen makes a cycle through plant and animal life.

Nitrogen is supplied to soil in another way. Although four fifths of the atmosphere consists of the element nitrogen, animals and most plants are unable to use this important element directly from the air. Fortunately there is one family of plants called *legumes* that assists in taking nitrogen directly from the air. Plants of the legume family like clover, peas, and beans have little nodules growing on their roots (see Fig. 343). In these nodules are certain bacteria that combine free nitrogen of the air with oxygen to form nitrates. A part of the nitrates is used by the plant and a large part stays in the nodules. When the plants die the nitrogen in the form of nitrates becomes a part of the soil. Many legumes do not grow well without these nitrate-forming bacteria in the soil. It is now possible to buy these bacteria and to inoculate[1] beans and other legumes with them before the planting is done.

U. S. Bureau of Plant Industry

FIG. 343. NODULES ON ROOTS OF A LEGUME

Most farmers do not raise the same crop, year after year, on a certain piece of land. Instead they alternate their other crops with legumes (peas, beans, clover,

[1] *Inoculate,* insert into (as buds, germs, or bacteria).

etc.) to enrich the soil with nitrogen. This method of farming is called *rotation of crops.*

Nitrogen, phosphorus, potassium, and calcium, the chemical elements most needed by plants, may be added to the soil by the use of commercial fertilizers. About a half billion dollars is spent in the United States each year for commercial fertilizers.

Fertilizers containing nitrogen are produced in several ways. Animal waste products of slaughter houses are ground up and sold. Large quantities of sodium nitrate (saltpeter) are imported into this country from Chile, where it occurs in natural deposits. A method has been discovered in recent years whereby nitrogen is extracted from the atmosphere and then used in the manufacture of nitrates valuable for fertilizing the soil.

Phosphorus is applied to the soil in the form of phosphates. Some fertilizers containing phosphates are made from the bones of animals and fish scraps. Others are made from phosphate rocks mined in the South.

Potassium comes from wood ashes or mined potassium salts. The Stassfurt mines of Germany are the greatest single supply of potassium fertilizer in the world. During the World War, when this supply of potassium was not available to the United States, American scientists developed methods of manufacturing potassium compounds from various sources of potassium in this country.

Lime, made from limestone, is a calcium compound sometimes added to the soil. In some cases the limestone itself is ground fine and used. If a soil is too acid, lime is added to neutralize the acid. When the acidity of the soil is reduced, certain beneficial bacteria are able to thrive better. These bacteria release more of the potassium, phosphorus, and other elements from the soil for use of the plants the farmer is raising.

Exercise. *From your study of this topic, cite evidence in support of each of the following statements.*[1]

1. *Soil is formed in different ways.*
2. *There are different types of soil.*
3. *Soil fertility depends upon several factors.*
4. *Soil water is important in crop raising.*
5. *Soil moisture may be conserved.*
6. *Soil fertility may be conserved in several ways.*
7. *Nitrogen goes through a cycle in nature.*

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chaps. 20, 37 (part)
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 21
Hunter and Whitman, *My Own Science Problems*, Unit 9; *Science in Our Social Life*, Unit 10
Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 14
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 2
Powers, Neuner, and Bruner, *The World around Us*, Chaps. 14, 15
Skilling, *Tours through the World of Science*, Tour 5
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 7
Watkins and Bedell, *General Science for Today*, Unit 3
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 4 (part)
Wood and Carpenter, *Our Environment: Its Relation to Us*, Topics 5, 6; *Our Environment: How We Use and Control It*, Topic 16

Special references

Washburne, *The Story of the Earth*
Fabre, *This Earth of Ours*
Thomson, *Outline of Science*
Fall, *Science For Beginners*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. The importance of fertile soil to mankind.
2. A thorough understanding of how to maintain and improve the fertility of soil.
3. How waste lands such as deserts and swamps have been made fertile for crop raising.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements and comply with the instructions.

1. The United States government has undertaken some irrigation projects in ____.
2. The water used for irrigation is usually supplied from ____.
3. Supplying water to the soil artificially is called ____.
4. Soil that has been built up from deposits by rivers is called ____.
5. Two leguminous plants are ____.
6. Humus is composed chiefly of ____.

Select the word or group of words which most satisfactorily completes each of the following statements.

7. Soils are classified according to their
   density   color   location   size of particle   capillarity
8. Soil that will hold water best is
   black   light   fine   coarse   full of gravel
9. The soil that is most likely to be sticky after a rain is
   sandy   stony   loam   clay
10. When different crops are planted in the same field in successive years the method of farming is called
    dry farming   irrigation   rotation of crops   reclamation
11. Our best all-around fertilizer is probably
    manure   lime   phosphate   potash   nitrate
12. Plants on which bacteria grow and which are able to take nitrogen from the air are called
    vegetables   legumes   nitrodes   cereals
13. Soil to be fertile must contain
    oxygen   carbon   copper   phosphorus   hydrogen

[1] See workbook, p. 77.

14. Capillary action causes water in soil to
rise fall evaporate flow away condense
15. Swampy lands have been reclaimed by use of
irrigation dry farming capillarity artificial drainage
16. An acid condition of the soil can be corrected by use of salt clover lime manure phosphate

SUPPLEMENTARY MATERIALS

Reading suggestions

Atkinson, *The Strange Adventures of a Pebble* (Scribner)
Mix, *Mighty Animals* (American Book)
Fairbanks, *Stories of Rocks and Minerals* (Educ. Pub.)
Grew, *The Romance of Modern Geology* (Lippincott)
Seers, *The Earth and Its Life* (World Book)
Tarr and Engeln, *New Physical Geography* (Macmillan)
Cole, *Rocks and Their Origin* (Macmillan)
Bradley, *Earth and Its History* (Ginn)
Reed, *The Earth for Sam* (Harcourt)
Husband, *A Year in a Coal Mine* (Houghton)
McCabe, *Ice Ages* (Putnam)
Whitlock, *The Story of the Minerals* (American Museum of Natural History)

Reports which may be prepared

1. The planetesimal hypothesis of the formation of the universe
2. Laplacian hypothesis of the formation of the universe
3. The Mammoth Cave of Kentucky
4. The Luray Caves of Virginia
5. How mountains were formed
6. Irrigation projects in the southwestern part of the United States
7. Factors which determine soil fertility
8. Fertilizers
9. Life in the Ice Age
10. How stalactites and stalagmites are formed in caves
11. The dangers of dust storms
12. How soils are conserved

Great scientists you should know about

1. Laplace
2. T. C. Chamberlin
3. F. R. Moulton

Investigations and things to do

1. Make a collection of rocks and minerals. Identify and label as many of them as you can.
2. Visit a museum and examine the specimens of rocks and minerals. You may find it interesting and valuable to compare your own specimens with those in the museum.
3. Make excursions into the surrounding country and note all the effects of weathering that you find.
4. Find out whether the section in which you are living was ever passed over by a glacier. If it was, make a field trip to find some evidences of it. Report your findings to the class.
5. Investigate carefully the kinds of soil in your community. Examine specimens for color, texture, water-holding ability, and fertility.
6. From what sources are our artificial fertilizers such as nitrates and phosphates obtained?

UNIT X. LIFE ON THE EARTH

Every object in the world can be classed as either a living thing or a non-living thing. Have you ever thought of the great variety of living things which inhabit our earth? Thousands of different kinds of animals and nearly as many different kinds of plants are known. There are also many kinds that have not yet been named and described in scientific literature.

The number of kinds of plants and animals living on the earth today is small, however, compared to the number of kinds that have lived and perished. From a study of layers of rock which contain imprints and remains of living things, we learn that plants and animals have lived on this earth for millions of years. Many kinds have become extinct because they failed to adjust themselves to a changing environment. Less than a hundred years ago there were millions of passenger pigeons on this continent; today there is not a single one.

In some respects this unit about life on the earth is the most important unit in the entire course. Man's progress from savagery to his present form of civilization has been due in large part to his ability to modify his environment and improve his living conditions. We are anxious that you master the scientific principles underlying the origin, life processes, and improvement of living things, and especially the improvement of man himself. The work of the world cannot be carried on by weaklings. The future progress of mankind depends in a large measure upon the removal of unfit persons from society and the improvement of the fit.

What do you already know about living things?

1. Have you ever seen any two living things exactly alike?
2. How many different kinds of living things are there in the world?
3. Where did life come from originally?
4. Why do you resemble your parents?
5. Where did our domesticated animals, such as horses, cows, dogs, pigs, and chickens, come from originally?
6. Where did our domesticated plants come from originally?
7. How are plants and animals improved today?
8. Is man in need of any improvement?
9. Can man be improved?
10. Who was Luther Burbank?

TOPIC 1. OUR SMALLEST LIVING THINGS

SUGGESTED PROBLEMS AND QUESTIONS

1. **What are bacteria? How large are they?**
2. **How do bacteria grow and reproduce? Under what conditions do they grow and reproduce best?**
3. **How do bacteria aid man in industry, in food manufacture, and in maintaining soil fertility?**
4. **What is the relation of bacteria to disease?**
5. **How do persons become immune to a disease?**
6. **How do bacteria enter the human body?**
7. **What can an individual do to help his body resist disease?**

SUGGESTIONS AND HELPS FOR STUDY

1. Since bacteria are very small it is necessary to look at them through a microscope. If you have a microscope available, prepare some cultures of bacteria and study them. Directions for making cultures are given in the experiments of this topic.

2. Keep in mind as you study this topic that some bacteria are very useful to man while some are deadly enemies which cause disease.

3. Be sure you understand problems 4, 5, 6, and 7. Gather all the information you can find in the references relating to these problems and master it. Every person should know how diseases are caused and how to prevent and control them.

4. Study the meanings of the following words:

environment—the surroundings of living things.
bacteriology—a study of bacteria.
disinfectant—something which kills bacteria.
antitoxin—a substance injected into the body to overcome the effects of some disease germ.
antiseptic—capable of killing germs.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 134. What are bacteria and how do they grow?

Put some leaves and hay in a dish of water. After several days, mount a drop of the liquid on a glass slide. Look at it through a microscope. Look for three different types of bacteria: rod-shaped or *bacillus* (băsĭl'ŭs), spherical or *coccus* (kŏk'us), and spiral or *spirillum* (spī-rĭl'ŭm). How many kinds can you distinguish? Do any of them move about? For continued study of bacteria it is desirable to prepare bacteria gardens. The following is a simple method:

[1] See workbook, p. 79.

Heat Petri dishes in a hot oven for two hours or keep them in boiling water for thirty minutes, to kill all bacteria.

Nutrient agar is an excellent food on which to grow bacteria. It can be prepared in the following manner. Peel and wash several small potatoes. Cut them into slices and boil in a quart of water for twelve minutes. Drain off about a pint of water from the potatoes and strain it through a clean white cloth. Cut a half ounce of agar (sea-weed jelly) into small pieces and stir it in the liquid. After a few minutes heat the solution again until the agar is all dissolved. Strain the liquid again and pour it into test tubes, making them about half full. Plug each tube with a wad of cotton. Stand the tubes in a dish of water. Boil the water for thirty minutes. The agar is now ready for use in bacteria gardens.

Experiment 135. Where are bacteria found?

Prepare some culture plates by putting some of the sterilized nutrient agar in several of the sterilized Petri dishes. If the agar in the test tubes has jellied from cooling, it will be necessary to melt by heating the test tubes in a beaker of water. Allow them to cool. Expose one dish to the air. Touch another here and there with your fingers. Hold another in front of some person's face when he sneezes. Sterilize the end of a thin wire by heating it in a flame and touch it to the cavity of a decayed tooth; then touch the agar in several places in one of the dishes with the wire. Cover the dishes and set them aside in a warm, dark place for several days. On the floor under a radiator is a good place. Examine them each day and record your results in your notebook.

Experiment 136. How may bacteria be killed?

Pour some melted nutrient agar into four test tubes. Label the tubes 1, 2, 3, 4. Find a Petri dish with colonies of bacteria growing in it. Touch the colonies with the tip of a needle which has been sterilized by holding in a flame and transfer some of the bacteria to the agar in each of the test tubes. Add a teaspoonful of iodine solution to the agar in test tube number 2. Add a teaspoonful of hydrogen peroxide to test tube number 3. Add a teaspoonful of some common disinfectant such as Zonite or Lysol to tube number 4.

Pour the contents of each test tube into a separate Petri dish. Label each dish. Put the dishes in a warm, dark place. After four days examine the Petri dishes again.

Are colonies of bacteria growing in dish No. 1? In dish No. 2? In dish No. 3? In dish No. 4?

Why did bacteria grow in one Petri dish and not in the others?

Why do we put iodine or hydrogen peroxide on a wound? Did you ever gargle your throat? Why?

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What are bacteria and how large are they? Bacteria are the smallest and simplest living things. They are tiny one-celled plants. They are not green in color because they do not possess chlorophyll. Hence they are not able to manufacture their own food, but are dependent upon other living organisms for their nourishment.

There are many kinds of bacteria, and they are found almost anywhere. There is no difficulty in getting material for study. Bacteria are in the air, in the soil, and in water. They may live on either dead or living material. A poorly ventilated schoolroom contains many bacteria in the air, and even a well ventilated room has some. Soil that is rich in decaying plant and animal life teems with bacteria. We eat, drink, and breathe bacteria in countless millions; yet most of them do us no harm. We shall learn later about bacteria that cause human diseases.

FIG. 344. KINDS OF BACTERIA

Single bacteria are so small that they are visible only when greatly magnified by a microscope. They range in size from about 1/25,000 to 1/1,000 of an inch in length. Only colonies containing millions of bacteria can be seen with the naked eye. Many persons who have never seen bacteria imagine them to be horrible looking creatures. They are, however, very simple in structure. They are generally colorless, transparent cells.

There are many kinds of bacteria. Most of them may be grouped as one of three forms. The three forms are shown in Figure 344, but keep in mind that they are greatly magnified in these diagrams. The straight, rod-like ones are called bacilli; the spherical ones are called cocci; and the curved and spiral ones are called spirilla. If a microscope is available in your school, scrape the inside of your cheek with your finger nail. Place the material on a slide, add a drop of water, and cover with a cover glass. Examine it with the high power of the microscope and you may see all three of these forms. These bacteria from your mouth are not particularly harmful. Among the many that may be moving, observe the characteristic snaky motion of the curved ones (spirilla).

How do bacteria grow? Like higher forms of life, bacteria have certain definite requirements for growth. Conditions of temperature, light, water, and food supply must be suited to their needs. Bacteria differ greatly in their requirements, and some of them are able to survive almost anywhere.

Water. Water is a first essential in the life of bacteria. Their bodies contain about eighty-five per cent water, and all of their food must be dissolved in water before it can be absorbed. Therefore bacteria live in liquids, and if the medium on which they live dries

out, they become inactive and may die. Some bacteria remain alive for months and perhaps years after drying. Fortunately most disease-producing bacteria are soon killed by drying.

Light. Most bacteria are killed by exposure to direct sunlight for even a few hours. Hence bacteria live in places where continued direct exposure to sunlight is not likely to occur, such as in soil, in foods, or inside the bodies of plants and animals. The killing action of sunlight on bacteria aids in the purification of streams and in the destruction of bacteria in our homes and on our streets and sidewalks.

Temperature. The best temperatures for bacterial growth are between 70°F. and 100°F. Very few bacteria grow well above 115°F., though in hot springs certain bacteria have been found growing at temperatures as high as 175°F.

Within certain limits a rising temperature speeds up the life processes in bacteria, whereas a falling temperature retards their life processes. Ordinarily all active bacteria are killed by boiling water. Their life activities are checked as the freezing point of water is approached and cease entirely when the water freezes. Freezing, however, does not kill bacteria; they may live in ice for months and become active again when the ice melts.

Food supply. Most bacteria require foods prepared by other living things. These foods are oxidized in their bodies by oxygen they obtain from air dissolved in the water surrounding them. The nitrifying bacteria of soils that break down dead plants and animals are exceptions to these statements. These nitrifying bacteria resemble green plants in that they are able to build their own foods from carbon dioxide, water, and mineral salts. They differ from green plants, however, in that they are able to manufacture their foods without the aid of sunlight. They obtain their energy from chemical action.

How do bacteria reproduce? Bacteria reproduce by dividing. One divides in the middle, forming two; each of these divides, making four (see Fig. 345). The cells grow quickly to full size and in many forms the dividing may take place every half hour. It is interesting to calculate how many bacteria would be formed from a single bacterium at the end of three days, if they divided every half hour and if all lived. It has been calculated that at the end of the first day (24 hours) there would be 281,000,000,000,000 of them, about one pint, formed from one bacterium. At the end of the second day there would be 281,000,000,000,000 pints, and at the end of the third day there would be enough to make 33,000 bodies as large as the earth.

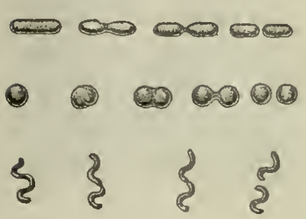


FIG. 345.
BACTERIA DIVIDING

Obviously they do not multiply so fast, otherwise the world would be covered with bacteria in a short time. Various agencies keep them down. Unfavorable conditions of moisture, temperature, and light kill many of them. Millions of them are eaten by microscopic animals. Harmful substances that prevent their growth are produced by the bacteria themselves, in the liquids surrounding them.

If conditions are unfavorable many bacteria decrease in size and form a thick wall around themselves. In this form they remain inactive until conditions are again favorable for their development. A bacterium in this dry and hard-walled state is called a *spore*, and may easily be carried about by the wind. Fortunately most disease-producing bacteria do not form spores; therefore, they are not likely to be found in dust. Spore formation in bacteria is not a method of reproduction, because there is no increase in numbers. It is a method by which certain bacteria live through unfavorable conditions. Spores are not killed by drying, and certain forms withstand the heat of boiling water.

How do bacteria aid man in industry, in food manufacture, and in maintaining soil fertility? Many bacteria are beneficial. In fact, in many ways the beneficial effects of bacteria are greater than their injurious effects.

Bacteria are useful in certain industries. In tanning leather, the hides are put into solutions of tan bark, where bacteria assist in making leather soft. Bacteria are valuable in preparing linen fibers. Linen fibers come from the flax plant. Flax is cut, put into pits, and kept moist. Bacteria cause rotting of the substances that hold the fibers of the flax plant together. The fibers are then separated and used in the manufacture of linen. This natural process is used in Ireland, where the best grades of linen are produced. In the United States an artificial process that requires less time is employed, but a poorer grade of flax fibers is obtained.

Bacteria are useful in the preparation of certain foods. Certain bacteria change alcohol into vinegar. The sugars in fruit juices are converted into alcohol by yeast; then the alcohol is converted into vinegar by bacteria. Certain other bacteria convert the sugar (lactose) in milk to *lactic acid.* This process is commonly spoken of as *souring* of milk. The presence of lactic acid in milk is necessary in the making of sour-milk cheeses such as our common Swiss cheese. Lactic acid bacteria are also useful in the making of sauerkraut. When cabbage is finely chopped, salted, and packed tightly in containers, the juice of the cabbage

is extracted by the salt. Lactic-acid bacteria that live and grow in the juice from the cabbage attack the cabbage and change it into sauerkraut.

Bacteria are useful in agriculture. The importance of bacteria in maintaining soil fertility was discussed in the unit on rocks and soils. Growing plants remove important chemical elements from the soil. Bacteria of decay attack plant and animal remains and decompose the complex substances of their bodies into simpler substances. These simpler substances are used over again by other plants. Were it not for the action of these helpful bacteria, nitrogen and other necessary elements would soon be gone from the soil, and all plant life on the earth would cease.

What is the relation of bacteria to disease? When certain bacteria live and grow in the human body, they give off poisonous substances called *toxins* (poisons). These poisons are carried by the blood to all parts of the body, and they cause illness by interfering with the normal activities of the body. To counteract the toxins, the body produces substances called *antitoxins*. If the body is able to produce antitoxins faster than the bacteria produce toxins, the disease is checked. If not enough antitoxins are produced, death may result.

How do persons become immune to a disease? Not all persons are equally susceptible to all bacterial diseases. If disease-producing bacteria enter an individual's body, but he is able to resist the disease, he is said to be *immune* to that disease. An individual that possesses immunity to a disease from birth has *natural immunity* to that disease. Members of the same race of people differ in their ability to resist diseases. Some children, for example, are naturally immune to diphtheria, whereas others have no resistance to it. Also there are racial differences. The white race is fairly resistant to tuberculosis, whereas Eskimos, Negroes, and Indians are highly susceptible to this disease. Measles is often fatal to natives of certain South Sea islands, but it is a relatively mild disease with white people.

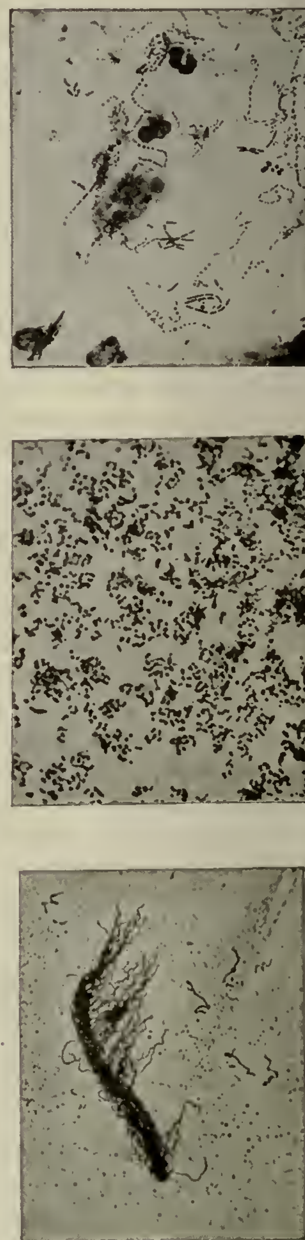
Immunity developed during the lifetime of a person is called *acquired immunity*. Immunity may be acquired in three different ways.

By having the disease. Persons who have had measles, smallpox, diphtheria, scarlet fever, mumps, or whooping cough do not usually have the same disease again. Unfortunately not all diseases produce immunity in those who recover from them. Influenza and pneumonia may return many times. Immunity develops during the course of these diseases, and the patient recovers from them, but the immunity does not last long.

By vaccination. Vaccination consists of injecting dead or weakened germs into the body. The toxins that these germs produce stimulate the body to produce its own antitoxins. Dead bacteria are used in vaccination against typhoid fever. Weakened germs from a cow are used in smallpox vaccination.

The history of smallpox vaccination is interesting. Vaccination was practiced in the Orient centuries ago. The people would obtain pus or scabs from a smallpox patient and put it into a cut or scratch of a well person. This caused the disease and developed immunity in those who recovered. This method of vaccination was introduced into England from Constantinople during the eighteenth century.

It has been observed for a long time that persons who had contracted cowpox, a disease of cows, were immune to smallpox. Edward Jenner (1749-1823), an English physician, proved by a series of brilliant experiments that cowpox is a form of smallpox and that having cowpox makes one immune to smallpox. After Jenner made known his experiments to the world, much opposition developed against his method of vaccination. Newspapers bitterly attacked the method, but the successful results obtained led eventually to the adoption of Jenner's vaccination for the control of smallpox and to the prevention by law of the older and dangerous method. Vaccination was introduced into this country about 1800. There are still a number of states that do not have compulsory vaccination.



School of Medicine, Washington University

FIG. 346. DISEASE GERMS

Top—Tuberculosis
Middle—Diphtheria
Bottom—Typhoid

By injection of a toxin. Immunity to diphtheria is produced in children by injecting a mixture of toxin and antitoxin. The toxin stimulates the body to develop its own permanent immunity, while the antitoxin lessens any ill effects the toxin might otherwise produce. Immunity

to scarlet fever is developed by use of small quantities of the scarlet fever toxin alone.

How do bacteria enter the human body? Bacteria may enter the body through the digestive tract. They may be in the food we eat. Typhoid fever and tuberculosis bacteria are sometimes taken in with milk or water. Drinking cups, pencils, toys, our hands, and other objects may have germs on them and infect us if we put them into the mouth. Common colds, diphtheria, and scarlet fever are known to be spread in this way.

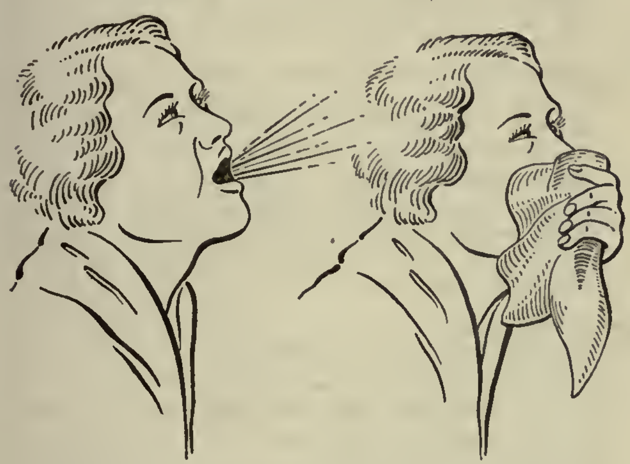


FIG. 347. SNEEZING THE WRONG WAY AND THE RIGHT WAY

Another common avenue of invasion for bacteria is through the nose. Droplets of sputum are thrown into the air when people sneeze and cough, and these are breathed in by other persons who may be near. Bacteria that produce colds, pneumonia, and diphtheria often enter the body in this way. A handkerchief should always be held over the nose and mouth while one is coughing or sneezing.

Certain germs enter the body through breaks in the skin. Cuts and scratches serve as an entrance for bacteria. Germs of tetanus (commonly called lockjaw) enter the body by this avenue. Certain insects puncture the skin of the body and thus introduce germs. The germs of malaria, yellow fever, and African sleeping sickness are transmitted in this manner; however, the germs that produce these diseases are not bacteria but are tiny one-celled animals.

What can an individual do to help his body resist disease? All diseases that spread in a community are caused by germs. Every person who has a contagious disease must have received the germs from someone else who had the disease or from some animal that was infected. A person need not always come in direct contact with a patient, for a number of contagious diseases may be spread through air, food, or water. Contagious diseases would probably disappear entirely if people who have them were careful not to spread them.

There are a number of ways in which every person can help control diseases. The appearance of such epidemic diseases as influenza, smallpox, diphtheria, infantile paralysis, and scarlet fever should be reported immediately to the Health Department. The house of the patient will be quarantined by the health officer, who places a card on the front of the house, warning people not to enter. In some communities people afflicted with dangerous contagious diseases are kept separate in special hospitals provided for this purpose.

Everything about a sick person should be carefully disinfected. Clothing and dishes taken from the sick room should be immediately treated with substances that will kill germs. All discharges from the patient should be properly disinfected. Various chemicals such as bichloride of mercury, carbolic acid, and chlorinated lime, all powerful disinfecting agents, are available for this purpose.

Sometimes powerful gases are generated in a sick room at the end of the illness. Formaldehyde and sulphur dioxide are the chemicals most commonly used. This process is called *fumigation*. Fumigation is not now considered important and is seldom used except to destroy insects.

If epidemics of smallpox or typhoid fever occur, every person in the community should be vaccinated. It is important to remember that vaccination does not produce immunity for life. In the case of smallpox vaccination, immunity lasts for about seven years. If you were vaccinated when you were six years old and you are now fourteen years old, you probably are no longer immune to smallpox germs. Therefore you should be vaccinated again. A large number of states require vaccination of all children before they enter school, but very few, if any, require vaccination more than once. In view of the fact that vaccination does not give immunity for life, do you think that states should require vaccination of its citizens more than once during a lifetime? Perhaps you can arrange to debate this question in your general science class.

With the introduction of the microscope as a tool of science came the discovery of the world of tiny plants and animals. Anton van Leeuwenhoek (lā′ven-hook), a Dutch clothing merchant, who ground lenses as a hobby, was the first to devote much time to the study of living things with a microscope. He made and perfected his own instruments.

In 1683, Leeuwenhoek announced his discovery of bacteria, and from the sketches and descriptions he made of them, we believe that he saw all three forms —round, rod-shaped, and spiral. Almost two hundred years elapsed, however, before the connection between bacteria and diseases was suspected. It remained for Louis Pasteur, a French scientist, about 1860, and later Robert Koch, a German experimenter,

to discover definitely the effects of bacteria on animals. The investigations of Pasteur, Koch, and Lister, an English physician, led to the development of the science of bacteriology. With the establishment of the germ theory of disease and the understanding of infections came new knowledge of immunity, of toxins and antitoxins, and of the theory and practice of inoculations and vaccinations.

Courtesy Bausch and Lomb Optical Company

FIG. 348. ANTON VAN LEEUWENHOEK (1632-1723)

It would be difficult to estimate the value to the human race of the work of such men as Pasteur, Koch, and Lister. Read other books about the lives and works of these men. The life of Louis Pasteur is especially interesting. It is said that when a Paris newspaper, years ago, asked its readers to vote as to who was the greatest living Frenchman, the choice of the people was not a soldier or a politician, but Pasteur, a man of science.

William Thompson

FIG. 349. LOUIS PASTEUR

Exercise. *In the light of your study of this topic, write a paragraph stating clearly the obligation of an individual in protecting others when that individual has a contagious disease.*[1]

Exercise. *Tell what precautions you would use to protect yourself if an epidemic of contagious disease broke out in your community.*

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chaps. 23, 24
Clement, Collister, and Thurston, *Our Surroundings,* Chaps. 22, 23, 35
Hunter and Whitman, *My Own Science Problems,* Unit 11 (part); *Science in Our Social Life,* Chaps. 12-15
Lake, Harley, and Welton, *Exploring the World of Science,* Chaps. 28, 32, 33
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 7
Powers, Neuner, and Bruner, *The World around Us,* Units 2, 8; *This Changing World,* Chap. 21; *Man's Control of His Environment,* Chap. 26
Skilling, *Tours through the World of Science,* Tour 17
Watkins and Bedell, *General Science for Today,* Chap. 29
Wood and Carpenter, *Our Environment: How We Use and Control It,* Unit 7

Special references

Ealand, *The Romance of the Microscope*
Kendall, *Civilization and the Microbe*
Conn, *Bacteria, Yeast, and Molds in the Home*
Conn, *The Story of Germ Life*
De Kruif, *Microbe Hunters*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Understand thoroughly what bacteria are, and the conditions under which they grow and reproduce.
2. Know in what ways bacteria aid us.
3. Know in what ways bacteria are our enemies.
4. Understand thoroughly the relationship of bacteria to human diseases.
5. Know how to guard the human body against invasions by disease-producing bacteria.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements and comply with the instructions.

1. Bacteria are one-celled ____.
2. Plants that are hosts for bacteria which take ____ from the air are called ____.
3. Milk is turned sour by ____.
4. Three ways in which bacteria are useful to man are ____.
5. Five human diseases which are caused by bacteria are ____.
6. Disease bacteria in the human body give off poisons called ____.
7. The agent used in the treatment of diphtheria is ____.
8. The modern process of vaccination for smallpox was discovered by ____.
9. Milk is pasteurized in order to ____.
10. Write a paragraph discussing various methods in use at the present time to combat disease bacteria.

[1] See workbook, p. 80.

TOPIC 2. OTHER ENEMIES OF MAN

SUGGESTED PROBLEMS AND QUESTIONS

1. **Why is the house fly a deadly enemy of man?**
2. **What is the life history of the house fly?**
3. **How can we protect ourselves from flies?**
4. **What is the life history of mosquitoes?**
5. **How can we control mosquitoes?**
6. **Why is the rat often spoken of as the "national pest"?**
7. **How is plant life affected by insect pests?**
8. **How are insect pests controlled?**

SUGGESTIONS AND HELPS FOR STUDY

1. Insects are important as carriers of disease germs. Flies and mosquitoes are the worst offenders in this respect. Be sure to make a careful study of these two forms.

2. Read several references on the questions and problems in this topic.

3. The scientific control of animal pests depends upon our knowledge of their life histories and their breeding places. Outline this information for each of the pests mentioned in the problems.

4. Study the meanings of the following words:

germs—any microscopic plant or animal organisms that cause diseases.

regurgitate—to pour back again. The fly pours partly digested food from the stomach back into the mouth.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Activity 137. What are some common animal pests? How can we combat them?

Among the animal enemies of mankind are the fly, mosquito, clothes moth larva, bedbug, rat, mouse, louse, and cockroach. In your notebook, state how each of these is a pest and how it may be combated.

Experiment 138. What is the life history of flies?

Place some fresh meat in a glass jar where flies may feed upon it. Examine it for fly eggs, and after you have found some, cover the jar with mosquito netting. Watch their development into adult flies and keep a record of the stages through which they pass. Also keep a record of the time.

In your notebook record your findings and answer the following questions. What are the four stages in the life history of a fly? Where does the house fly usually lay its eggs? What is the larva of a house fly called?

Experiment 139. What is the life history of mosquitoes?

Place a can of water under some bushes or in high grass where mosquitoes are known to be. Mosquitoes lay their eggs on stagnant water. Bring the can into the classroom and cover it with mosquito netting. Observe the developments which take place.

[1] See workbook, p. 80.

Put some mosquito larvae in another jar or can (the larvae usually can be found in rain barrels, old cans with water in them, or water puddles). Add some kerosene to the water.

Put a goldfish or a minnow into a jar containing mosquito larvae.

In your notebook record your findings and answer the following questions. What are the four stages in the life history of mosquitoes? Where do mosquitoes lay their eggs? How may mosquitoes be combated? Do mosquitoes in your locality carry disease germs?

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

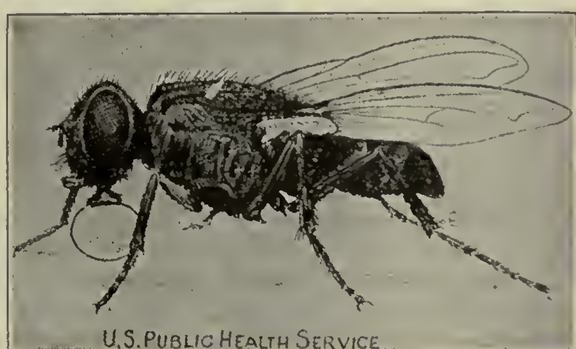
1. Make a survey of your home and collect specimens of all insects you see. Determine whether these insects are harmful or useful.

2. Make a survey of your community and find all the places where flies and mosquitoes may breed. Report your results to the class and suggest ways of remedying the situation.

3. Make a special investigation of animal pests that destroy food and clothing.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

More than seven hundred thousand different kinds of animals inhabit the earth. All are adapted to their surroundings; otherwise they could not live. They have needs similar to ours although often the methods



Bureau of Public Health Service

FIG. 350. REGURGITATION OF FOOD BY A HOUSE FLY

of satisfying them may be different. Man dominates all other forms of life, but his supremacy is not maintained without a struggle. In some parts of the earth people still live in fear of lions, tigers, and huge snakes. In our own country, we are no longer forced to match our skill with the cunning of wild beasts, but we are constantly at war with insects and other animal pests that destroy our food supply and spread deadly diseases. There is scarcely a crop of any kind

that is not injured in some way by insects. The struggle between man and insects is intense, and it never stops. The insects keep everlastingly at it, and so must we. In this topic we shall learn about some of the most dangerous enemies that man must combat.

Why is the house fly a deadly enemy of man? Less than a hundred years ago people in general thought that flies were harmless, and some persons advocated protecting them. Today we know that house flies distribute disease germs that cause the death of many human beings each year.

The house fly carries disease germs in several ways:

1. If you examine a house fly (preferably with a hand lens) you will notice that its feet and legs are very well adapted for carrying bacteria. The feet are sticky and the legs have many hairs which take up bacteria (see Fig. 350). Flies become soiled with the filth in which they live, and some of this filth is left upon any object the fly touches. More than 6,000,000 bacteria have been found on the body of a fly from a filthy place. The average number of bacteria on flies is about 1,500,000.

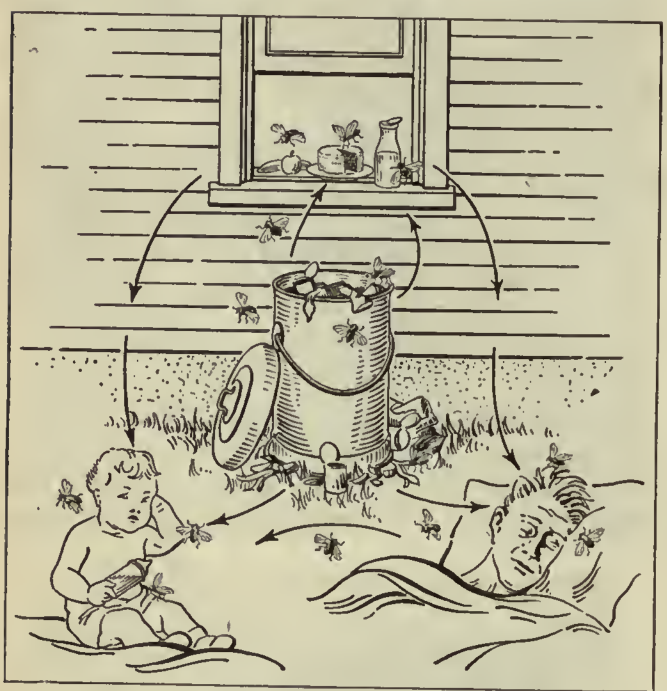


FIG. 351. HOUSE FLIES AND DISEASE

2. Flies regurgitate some of their food. After a fly has eaten heartily from a garbage can or a swill barrel, it may enter the house and regurgitate some of the contents of its stomach on our food. If bacteria are present they will be taken into our digestive system and may produce disease. Solid substances such as sugar crystals must be dissolved before the fly can swallow them. When a fly eats sugar it pours out saliva which dissolves some of the sugar crystal. Then it draws the dissolved sugar into its stomach. If the saliva contains bacteria, some of them may be left on the food.

3. Flies deposit waste matter called *fly specks* on food. Bacteria may pass completely through the digestive system of a fly without being killed. If a fly has been feeding in a filthy place, the fly specks may contain bacteria capable of producing disease.

Germ diseases are carried by house flies. Typhoid fever is perhaps the most common disease spread by flies. It is for this reason that the house fly is now often spoken of as the *typhoid fly*. Typhoid bacteria lodge principally in the intestines of man. The germs are taken into the body with foods, especially with liquids such as milk and water. The germs are discharged from the body in excretory matter and in sputum. Flies may carry the typhoid bacteria from human wastes and sputum to food. Therefore it is of utmost importance that excretions and sputum from typhoid patients be treated in such a way that all germs are destroyed. Sometimes people seem to recover from typhoid fever and yet continue to excrete typhoid bacteria. Such persons are known as "carriers." It has been definitely established that the presence of unrecognized "carriers" and a large number of flies with access to food supplies has been the cause of typhoid fever epidemics in certain communities.

Flies carry tuberculosis germs and they help spread the disease. Flies alight on sputum and take some of it into their bodies. If bacteria are present they may remain alive in the intestines of the fly for days and be deposited with waste matter. The sputum from tuberculosis patients should always be destroyed in order that flies may not get to it. Flies are known to spread other diseases. Many children suffer and a large number die each year from summer diarrhea. The number of cases of this disease varies according to the number and activity of house flies.

What is the life history of the house fly? In order that we may know how to control and exterminate flies, it is necessary that we know where and how flies breed and develop. About ninety-five per cent of all house fly eggs are laid in horse manure. The eggs may also be deposited in various kinds of garbage, other animal excreta, and decaying vegetable matter. The development of the automobile as a means of transportation has caused a decrease in the number of flies in many communities. Why?

Flies begin to breed in early summer and continue multiplying until fall. The female fly lays about five hundred eggs. Within twenty-four hours an egg develops into a larva, commonly called a *maggot* (Fig. 352). The fly lives as a maggot on the filth surrounding it for five days and then forms a *pupa*. The pupa

is the resting stage of an insect between the larva and the adult stage. About four days later the adult fly emerges from the pupa. The adult female is ready to lay eggs about two weeks after she emerges from the pupa. Thus in a little more than three weeks another generation of flies may be started.

How can we protect ourselves from flies? The most important method of controlling flies is to prevent them from breeding. If there were no breeding places, there would be no flies. Horse manure should be kept in covered containers or be treated with some substance that kills fly maggots. Chloride of lime may be used for this purpose. Garbage, slops, and refuse of all sorts should be kept in covered containers and destroyed at least once a week. Open toilets and cesspools should not be tolerated.

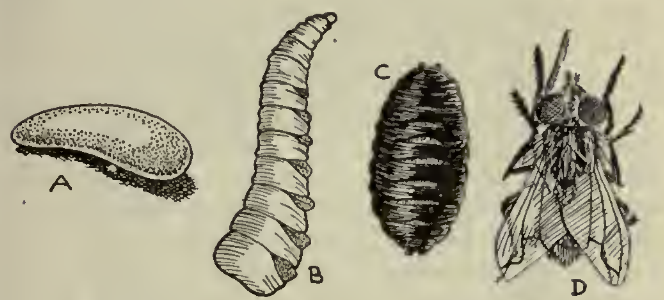


FIG. 352. STAGES OF DEVELOPMENT OF HOUSE FLY
(The egg is considerably magnified.)

Fly traps and fly poisons may also be used in combating flies. However, these methods are not so effective as the ones previously mentioned. Formaldehyde solution made by dissolving two teaspoonfuls of formalin in a pint of a mixture of milk and water is an effective fly poison. If this poison is used it must be kept away from small children.

Flies also have many natural enemies. Certain birds and insects destroy many flies. Frogs, toads, and lizards eat them for food, and the house centipede is a deadly enemy of flies. Many flies also die a natural death. A number of the more vigorous ones crawl into cracks and crevices and hibernate during the winter months. Most of the flies that appear in early spring, however, have spent the winter in the pupa stage.

Do you think that all flies could eventually be destroyed if we applied the scientific knowledge that we have? What is your community doing to combat flies?

What is the life history of mosquitoes? There are many varieties of mosquitoes, but fortunately only a few carry disease germs. In temperate climates but two common varieties are found. One of the two varieties is called *Culex* (kū'lěks). The common house mosquitoes belong to this group. They are annoying and a nuisance, but they are comparatively harmless. The other form is called *Anopheles* (ȧ-nŏf'e-lēz). This type transmits the malarial fever germ. In tropic regions a mosquito called *Aedes* carries the germ which causes yellow fever. See Figure 353, which shows the life history. Notice the differences in each stage of development.

The germ causing malaria is a tiny one-celled ani-

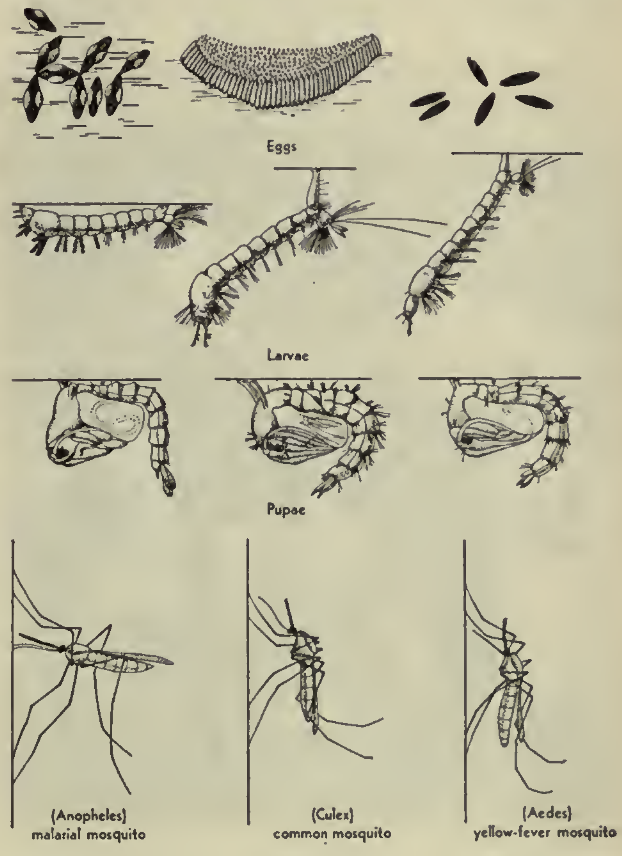


FIG. 353. LIFE HISTORY OF MOSQUITOES

mal that lives in the blood stream of the victim. The mosquito Anopheles penetrates the skin of a human being who is suffering from malaria and sucks up blood containing the malaria germs. The germs live in the body of the mosquito. When the mosquito bites another person, it leaves some of the malaria germs in the wound. These germs may then increase in number and cause malarial sickness in the second person.

Losses due to malaria are very great. In the United States several million cases of this disease occur each year. Although it is seldom fatal, it reduces greatly the working capacity of its victims. This results in a loss of millions of dollars to our nation each year. Malaria also lessens one's resistance to other diseases.

How can we control mosquitoes? Mosquitoes could be eliminated entirely by preventing them from breeding. Mosquitoes lay their eggs on stagnant water. In about three days the eggs hatch into larvae known as

"wrigglers." The larvae remain in the water feeding on the green scum on the surface. In about two weeks the larvae change to pupae, and about four days later the adults emerge from the pupae.

Since mosquitoes need stagnant water on which to lay their eggs, we can eliminate mosquitoes if we get rid of stagnant water or keep it covered. This is a difficult task requiring the cooperation of all. Swamp areas must be drained or filled with dirt. Water receptacles such as buckets, tin cans, rain barrels, and cisterns must be kept covered. Where it is not possible to remove all stagnant water, other methods may be used to prevent mosquitoes from breeding. Pouring kerosene on water kills the wrigglers because the film of oil that forms on the surface prevents them from getting air. Recently Paris green has been used successfully to kill mosquito larvae. Powdered Paris green mixed with dust (one part of Paris green to 100 parts of road dust) is thrown into the air so that the dust cloud will settle over the body of water being treated. In large swamp areas, the dusting is done from airplanes.

Keystone-Underwood

FIG. 354. POURING OIL OVER A POOL OF WATER TO KILL MOSQUITO LARVAE

Mosquitoes have many natural enemies. Frogs, toads, dragonflies, spiders, bats, and night-flying birds devour them in large numbers. Countless millions of the larvae and pupae are eaten by fish and other insect-eating animals. Sometimes fish are introduced into bodies of water to keep down the number of mosquitoes. The enemies of mosquitoes reduce their number, but do not prevent them from becoming a pest. The elimination of the mosquito depends upon cooperation of the citizens of each community. Are you bothered with mosquitoes in your locality? If so, it would be an interesting class project to survey your community to locate the breeding places of these mosquitoes.

In addition to house flies and mosquitoes certain other insects such as blood-sucking flies, lice, fleas, bedbugs, and roaches are known or believed to transmit diseases. Many of these insects live in filthy places and carry large numbers of disease germs on their bodies. Infantile paralysis and bubonic plague are sometimes transmitted to people by bedbugs and fleas. Typhoid fever and tuberculosis germs may be carried about by cockroaches. Sleeping sickness germs are transmitted by certain blood-sucking flies.

Why is the rat often spoken of as the "national pest"? It is one of the most destructive animals in the world. It has been estimated that more than $200,000,000 worth of produce and property are destroyed in the United States each year by rats. They eat the standing grain in the fields, the stored grain, and food in homes and stores. They kill small domesticated animals such as growing ducks and chickens. They gnaw holes in buildings and weaken the foundations with their burrows.

Of still greater importance is the fact that rats carry disease germs. Rats carry bacteria that cause the dreaded bubonic plague. This is primarily a disease of rats and other rodents. The disease is transmitted by fleas from one rat to another and from rats to man. Great epidemics of this disease have swept across Europe in the past, and it is estimated that during the fourteenth century 25,000,000 people died of bubonic plague. A few outbreaks have occurred in this country, but they were quickly suppressed by exterminating the rat and killing other infected animals. Rats that live in drain ditches and sewers come out at night and spread the germs of typhoid fever and other intestinal diseases.

Only by patient and persistent effort and the cooperation of all can a community be kept free from rats. Trapping them by combined action of all the members of a community is the best method. Barium carbonate mixed with food is recommended by the U. S. Department of Agriculture as an effective rat poison. The chief objections to the use of poison are its dangers to human beings and animals, and the possibility that rats eating it may die in inaccessible places, where their decaying bodies will cause bad odors. Cutting off the food supply limits the number

of rats that can live and reduces the breeding of rats. Hunger also makes trapping and poisoning more effective. Foodstuffs should be kept in rat-proof buildings and containers, and waste and garbage should be kept in tightly covered garbage cans. The uncovered garbage can is one of the common sources of food supply for rats.

How is plant life affected by insect pests? Only a few people are aware of the tremendous financial loss to people of the United States caused by insect enemies of plant life. Every kind of plant raised by the farmer, every kind of fruit tree, and every kind of forest and shade tree is subject to attacks by destructive insects. Recently experts of the United States Department of Agriculture estimated the annual loss in the United States due to injurious insects, as follows:

Courtesy U. S. Department of Agriculture

FIG. 355. FEEDING PLACES OF RATS

Farm crops

Cereals	$ 430,204,600
Hay	116,230,500
Cotton	165,000,000
Tobacco	16,900,800
Vegetables	199,412,600
Sugar crops	8,436,800
Fruits	141,264,300
Farm-forest products	22,138,900
Other crops	29,649,700
Total	$1,129,238,200
Natural forests and forest products	$ 100,000,000
Products in storage	100,000,000
Insect-borne diseases of man	150,000,000
Direct or indirect damage to domestic animals	100,000,000
Grand total	$1,579,238,200

Insects exist in greater variety and abundance than any other sort of animal life. Not all are injurious, however, and some have considerable commercial value. Unfortunately thousands of them infest plants.

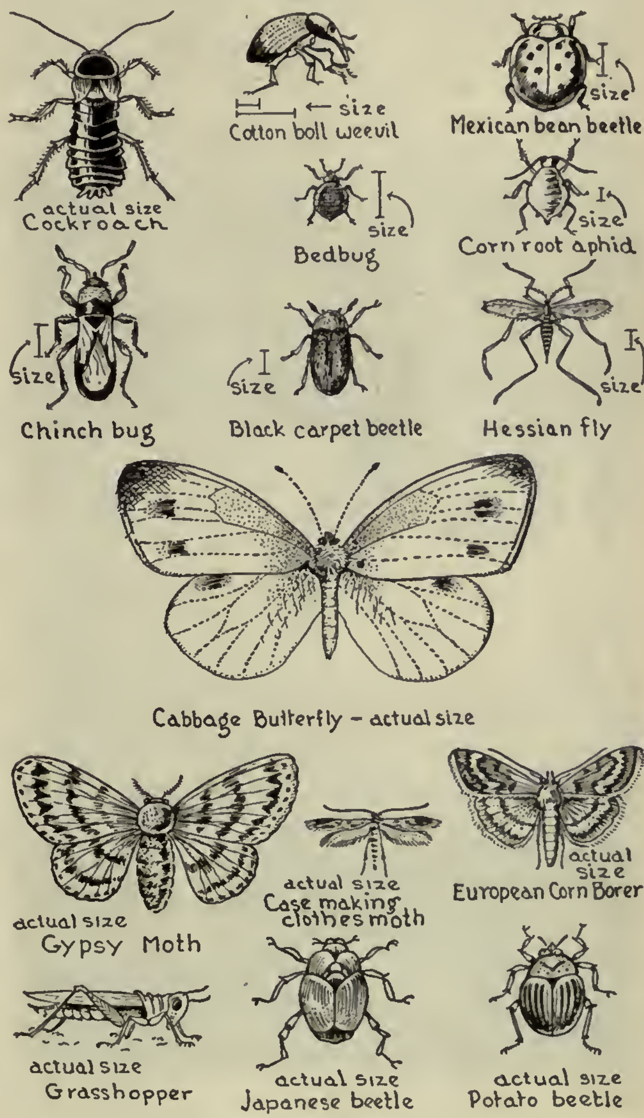


FIG. 356. INJURIOUS INSECTS

Some plants have as many as two hundred different kinds of insect enemies, but usually only a few of them are very destructive. Pictures of some of the most common insects injurious to vegetation are shown in Figure 356. If you are interested in the life histories of any particular ones, consult special references listed at the end of the topic.

In addition to native insect pests we must contend with certain introduced species. Some years ago the European gypsy moth and browntail moth became established here and destroyed many of the trees of New England. Already more than eight million dollars have been spent to hold this pest in check. The Euro-

pean corn borer, the larva of another moth, threatens to become a serious pest. It is believed to have been introduced into this country about 1917 and it has already spread as far west as Indiana. Since the larva lives inside the stalks of corn and other plants, the method of control is to burn or destroy in some other way the plant remains in which the insect is living. During the summer, in the eastern part of the United States, it is not an uncommon thing to be stopped on

Courtesy U. S. Department of Agriculture

FIG. 357. LIFE HISTORY OF THE JAPANESE BEETLE

the road by an officer, for an inspection of your car, to see whether you are carrying any plants that may spread the corn borer into some uninfested locality.

The Japanese beetle, introduced into New Jersey about 1916, is another foreign pest. The larva lives in the ground and eats grass roots while the adult insect feeds on fruit and leaves of many different kinds of plants. It multiplies rapidly and is gradually spreading to other states. Cultivation of the soil kills many of the larvae, and some of the adults are killed by poisoning. For various reasons, however, these methods have not been very successful, and at the present time quarantine is being attempted to prevent the spread of the pest while government experts search for other methods of control.

How are insect pests controlled? Intelligent control of insects requires a thorough knowledge of their life histories. People who specialize in the study of insects must become familiar with every stage of the life history of a pest and then determine how it can be controlled. Natural enemies are used to control certain insect pests. This method is called *biological control*, and it promises to play an important part in the control of insects in the future. At one time the orange and lemon industry of California was threatened with

California Fruit Growers Exchange

FIG. 358. RIDDING TREES OF HARMFUL INSECTS

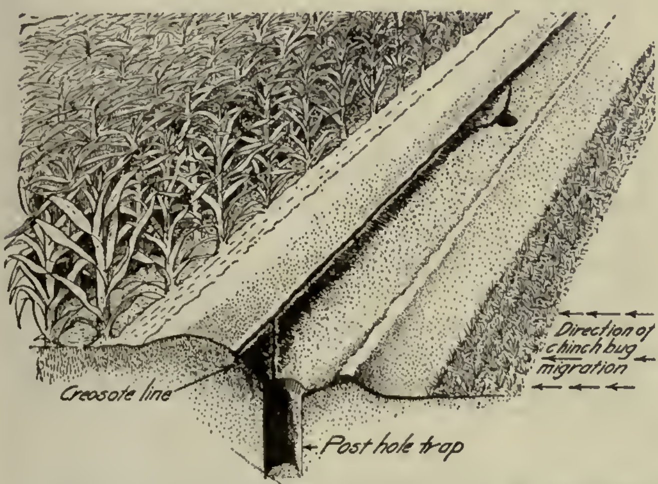
The trees are covered with canvas; then poisonous gases are pumped under the covering.

extinction because of a pest known as the cottony cushion scale. Mr. Albert Koebele of the U. S. Department of Agriculture, while collecting insects in Australia, noticed that this cottony cushion scale was being destroyed by the Australian ladybird beetle. Knowing this beetle was not a native of the United States, he introduced it into California, where it became so numerous that the cottony cushion scale was soon under control. Today the ladybird beetle is raised by the state of California, and whenever the cottony cushion scale becomes abundant some of the beetles are released. The result is complete control of the scale in a short time. Many artificial methods such as spraying, traps, crop rotation, and cultivation are also employed to control insect pests.

Spraying. This method of controlling injurious insects depends upon the ability of the substance used in the spray to kill the insect either by contact or by internal poisoning. In the case of insects like the Colorado potato beetle, which eat the leaves of plants, an

internal poison such as Paris green or lead arsenate may be sprayed on the leaves. However, an insect such as the chinch bug, which secures its nourishment by sucking plant juices, cannot be controlled by internal poisons. Sucking and boring insects are controlled by the use of some type of spray which will be absorbed through the outer covering of the body and thus kill them or by one which will clog up the spiracles, or breathing pores, and kill them by suffocation. Sprays of this sort commonly used are whale oil, soap, nicotine, and sulphur mixtures.

Traps. In a few instances some control over an injurious insect has been effected by the construction of traps of one sort or another. In Kansas the migration of chinch bugs has been controlled by the construction of post-hole traps. A barrier of creosote, which



U. S. Dept. of Agriculture, Bureau of Entomology and Plant Quarantine

FIG. 359. POSTHOLE TRAPS USED IN THE CONTROL OF THE CHINCH BUG

the chinch bug dislikes, is placed along an infested field. The bugs do not cross the barrier, but follow along it. At intervals these creosote barriers empty into post holes. The insects go into the hole and are destroyed by a suitable poison. See Figure 359.

Crop rotation and altered planting. Some insect pests feed only upon a single crop. In such cases, alternating this crop with one upon which the pest does not feed tends to starve out the insect and thus reduce its numbers materially. This method is used with considerable effectiveness in the control of the cotton-boll weevil in the South. Fields upon which cotton is grown one year are either left idle or planted to another crop the following year.

Knowing when an insect will appear to feed upon a given crop often proves helpful in protecting the crop. The planting of the crop may be either advanced or delayed so that it will mature before or after the appearance of the insect. Corn is frequently planted late to avoid the corn borer. Also some types of wheat, if planted late, avoid attacks by the Hessian fly.

Dusting. This method of control of insects is closely related to spraying. It consists of dusting the poison on the plant in the form of a fine powder. Both internal and contact poisons may be applied by this method. In recent years dusting cotton fields with calcium arsenate by means of airplanes has proved effective in the control of the boll weevil.

U. S. Dept. of Agriculture, Bureau of Entomology and Plant Quarantine

FIG. 360. DUSTING A FIELD OF COTTON WITH CALCIUM ARSENATE FOR THE BOLL WEEVIL

Plowing under and burning over. In some instances such as in the case of the European corn borer, the insect may live through the winter in the stubble which is left in the field after the crop has been harvested. Fall plowing of such fields or burning them over may greatly reduce the numbers of insects appearing in the spring.

Quarantine. After an insect pest has gained a start in a certain section of the country, it is important that it be prevented from spreading to other parts. To accomplish this purpose quarantine areas are often established. Patrols are placed along the highways to stop all vehicles leaving the infested area and to attempt to prevent the transportation of any materials across the line which might carry the insect in any stage of its life cycle.

The fight that man is carrying on to protect his crops and other resources from the ravages of insect pests is so important to every one that you should become familiar with some of the worst pests so that if the opportunity presents itself, you may engage in the war to exterminate them. As has been said, effective control can be brought about only when the life histories and habits of the pests are thoroughly understood.

Exercise. *Make an investigation in order to learn of the injurious insects and plant diseases at work on trees, shrubs, flowering plants, and crops in your community. Learn which methods of control are used and*

decide whether the methods used are the most effective ones. If possible, bring to class for further study some specimens of the insects or diseases at work.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 31
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 36
Hunter and Whitman, *Science in Our World of Progress*, Unit 16
Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 33
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 7
Powers, Neuner, and Bruner, *The World around Us*, Units 2, 8; *Man's Control of His Environment*, Chap. 9
Watkins and Bedell, *General Science for Today*, Chap. 29
Wood and Carpenter, *Our Environment: How We Use and Control It*, Unit 7

Special references

Atwood, *Civic and Economic Biology*
Doane, *Insects and Disease*
Howard, *The House Fly*
Hunter, *A Civic Biology*
Ritchie, *Primer of Sanitation and Physiology*
U. S. Dept. of Agriculture, *Farmers' Bulletin*, 459 and 851

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the common destructive insect pests.
2. The methods used to exterminate household pests.
3. The reasons why the house fly is our most dangerous household pest.
4. The life history of the house fly and of the mosquito.
5. The destructive work of rats and the best ways to eliminate them.
6. A knowledge of how to combat animals that destroy our food and clothing.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. List all the animal pests you know and state briefly the ways in which each is a pest.
2. The four stages in the life history of a fly are ____.
3. The larva of a fly is called a ____.
4. House flies lay their eggs in ____.
5. The mosquito that carries malaria germs is called ____.
6. The larva of a mosquito is called ____.
7. Mosquitoes lay their eggs on ____.
8. The best way to get rid of flies is by ____.
9. The best way to eliminate mosquitoes is ____.
10. Flies have been found to be carriers of the germs which cause the disease ____.
11. Clothes moths can be kept from destroying clothing by ____.
12. The best methods by which to get rid of rats and mice are ____.
13. Write a paragraph on the topic, "The Rat, Our National Pest."

TOPIC 3. THE ORIGIN AND DEVELOPMENT OF LIVING THINGS

SUGGESTED PROBLEMS AND QUESTIONS

1. What are living things made of?
2. What is the nature of cells, tissues, and organs?
3. Does life always come from life?
4. What is the structure and function of a flower?
5. How are seeds formed?
6. What is pollination? How many different agencies of pollination are there?
7. Do higher animals reproduce in a manner similar to flowering plants?

SUGGESTIONS AND HELPS FOR STUDY

1. Think over each problem carefully to see if you have any information about it already; then proceed to secure further material from the suggested reference studies.

2. It is easy to raise one-celled animals and yeast plants in the classroom, where their methods of reproducing may be observed through a microscope.

3. In the spring of the year female frogs and toads deposit their eggs in ponds. These eggs are easy to find and can be kept in an aquarium where their development can be observed.

4. The following words may be new and difficult for you. Study them carefully.

protoplasm—the living matter of plant and animal cells.
nucleus—the denser portion of a cell, usually in the central part.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 140. How do tiny one-celled animals reproduce?

Place a handful of hay in a jar of water and keep the jar in a warm place. After several days mount on a slide

[1] See workbook, p. 82.

some of the scum which has formed in the jar. Examine it under a microscope. Look for single-celled animals swimming about. By observing them for some time find out how they reproduce.

Activity 141. How do flowering plants reproduce their kind?

Read the text on pages 230-231 before performing this exercise. Examine carefully the parts of a typical flower. The

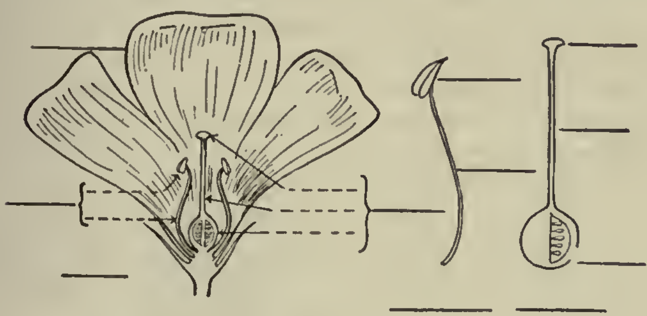


FIG. 361

flower of a gladiolus or a tulip makes a good specimen to study. Figure 361 is a diagram of a typical flower. Label the parts of the flower on a similar diagram. How is reproduction carried on by the flower?

Courtesy General Biological Supply House

FIG. 362. COLLECTING FROGS' EGGS

Activity 142. How do frogs reproduce?

Female frogs lay their eggs in the spring of the year. Visit a pond and look for frogs' eggs floating in the water. Collect a mass of eggs and keep them in an aquarium in the classroom. Watch them develop. Read in the text the description of how frogs reproduce.

In your notebook complete the following statements.

When frogs reproduce, a cell called the ____ unites with a cell called the ____. This process is called ____.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What are living things made of? When you look at a brick building from a distance, you cannot see the bricks of which it is composed. As you come nearer to the building, however, you observe that it is made of smaller units of matter or bricks. When you look at the leaf of a plant or the bone of an animal with the naked eye, each appears to be a solid mass. If, however, you were to examine under a compound microscope a thin section of a plant or scrapings from the inside of your cheek, you would see that they are composed of very small units. These units are called *cells*. If you were to examine, in a similar manner, bits of muscle, bone, nerve, or any other part of your body, you would find them also made up of cells (Fig. 363). All animals and plants are either single cells or com-

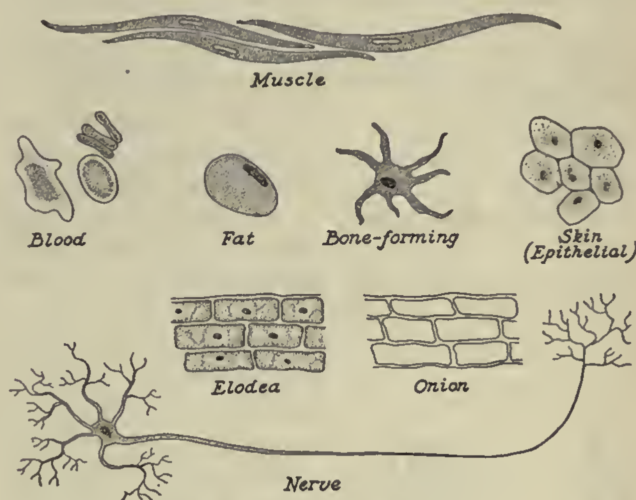


FIG. 363. TYPES OF CELLS

binations of cells, and the life of a living organism is the combined life of its individual cells.

There is great variation in the cell structure of living things. Some plants and animals are so tiny that their bodies consist of but a single cell. In a pond of water millions of tiny one-celled animals and plants may be living. Bacteria and yeasts are simple one-celled plants, but most of the plants and animals we know consist of many cells. Our own bodies are made up of countless millions of cells.

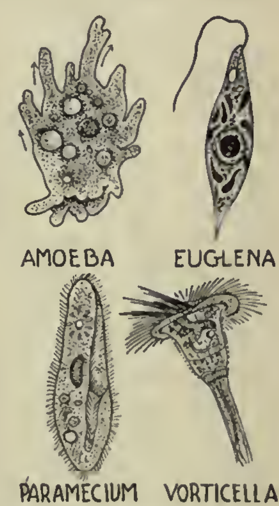


FIG. 364. ONE-CELLED ORGANISMS THAT LIVE IN WATER

What is the structure of cells, tissues, and organs? There is an almost endless variety in the shape, size, and structure of cells. Most cells, however, have certain things in common (see Fig. 365). They are generally surrounded by a *cell wall*, a thin layer that is somewhat harder than the contents of the cell. The most important part of the cell is the living matter inside it, a jelly-like substance called *protoplasm*. A part of the protoplasm is a tiny structure, usually of spherical shape, called the *nucleus*. A cell is, then, a bit of protoplasm containing a nucleus, and it is the simplest structure known to show the characteristics of life. Cells grow to a certain size and then divide. By means of this division a large

number of cells may be formed in the body of a plant or an animal.

If you were to examine a bit of muscle under a compound microscope you would find the cells more or less alike in size and shape. Masses of cells that are somewhat similar and that do the same work are called *tissues.* We have bone tissue, all made of bone cells; we have blood tissue, brain tissue, nerve tissue, and so on. When a number of tissues are combined to perform a definite work in a plant or animal, the structure so formed is called an *organ.* The heart is an organ made of muscle, blood, and nerve tissue. Its work is to pump the blood to all parts of the body. The organs of plants and animals are their most conspicuous parts. Is it not the root, the stem, the leaf, the seed, or the flower of a plant that attracts our attention? These structures are organs. Tissues and cells must be magnified before we are able to study them.

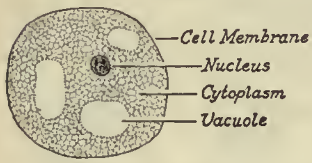


FIG. 365. DIAGRAM OF A CELL

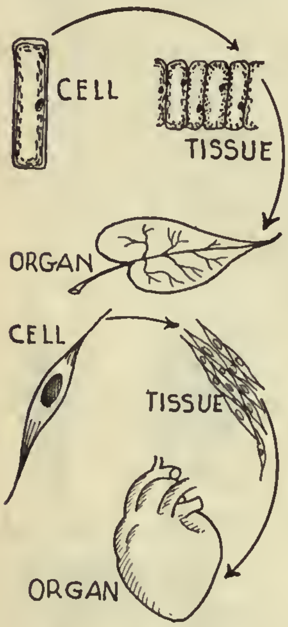


FIG. 366. CELLS, TISSUES AND ORGANS

Does life always come from life? It is customary in science to divide objects about us into two classes: living and non-living things. We are able to distinguish living from lifeless matter by differences that are easily recognized. All living things have the power to grow. They grow by taking in food, digesting it, and adding it to themselves. Lifeless matter is unable to grow in this way. Living things are active and are capable of independent movement while non-living things move only when acted upon by some external force. Plants and animals are more complex in structure than non-living matter. Their bodies are composed of cells, tissues, and organs, all highly organized and working together for the benefit of the individual.

A unique characteristic of living things is their power to reproduce their own kind. The ability to reproduce is found only in the living world. Until about the seventeenth century most people believed that some forms of life developed from non-living matter. It was thought that decaying meat produced flies, that fish developed from water, and that frogs came from slime. In 1680 Redi, an Italian, performed a simple experiment. He covered some meat in order that flies could not get to it and found that if flies were kept away from decaying meat, maggots would never develop in it. He concluded that life comes only from living things. His experiments started a dispute which in turn led many scientists to devise experiments to study the question of the origin of life. The dispute lasted for nearly two centuries until Pasteur and Tyndall, two famous scientists, by careful experiments proved that lifeless matter does not generate living matter. Today it is firmly established that all life comes from life.

Higher plants and animals are made of two kinds of cells. First, there are the ordinary *body cells* that make up the bones, muscles, nerves, and blood of animals, and the cells which form the roots stems, and leaves of plants. The others cells, called *germ cells* or *sex cells,* are set apart from the body cells early in the life of the individual. So much alike are the germ cells in both plants and animals that scientists use the same names in describing them. Female sex cells are called *eggs* (ova) and male sex cells are called *sperms.* Reproduction takes place through the uniting of a sperm cell with an egg cell. Since a new individual is formed by a union of cells from the parents, should we not expect the individual to resemble its parents?

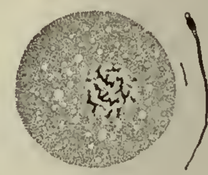


FIG. 367. EGG AND SPERM

What is the structure and function of a flower? The flower of a plant contains the reproductive organs. These organs produce the sperms and eggs that unite to produce more plants. The great variety and beauty of flowers attract our attention. We observe their different colors; sizes, and shape. Yet all complete flowers are much alike, in that they have the same kinds of parts. Figure 368 shows the structure of a typical flower. Study it carefully as you read. Also examine some live flowers and compare them with the diagram.

The buds of flowers are usually protected by a green, leaf-like covering. When a bud opens, these coverings are pushed apart and are called *sepals.* Next inside the sepals are the *petals,* the colored, attractive parts of the flower. Inside the group of petals is a circle of parts called *stamens.* In the *anther,* located at the top of the stamen, yellow *pollen* is produced. Inside the circle of stamens is the *pistil.* The enlarged base of the pistil is the *ovary,* in which the seeds develop. At the top of the pistil is a flat, sticky structure called the *stigma.* The stigma is connected with the ovary by the *style.*

The stamens and pistils are necessary for production of seeds and are therefore the essential organs of the flower. The stamens produce the sperm cells and the pistils produce the eggs. The sepals and petals protect the stamens and pistils and add to the attractiveness of the flower.

How are seeds formed? A seed contains a baby plant with a food supply to nourish it until it is able to make its own food. Let us learn now how seeds are developed by flowers.

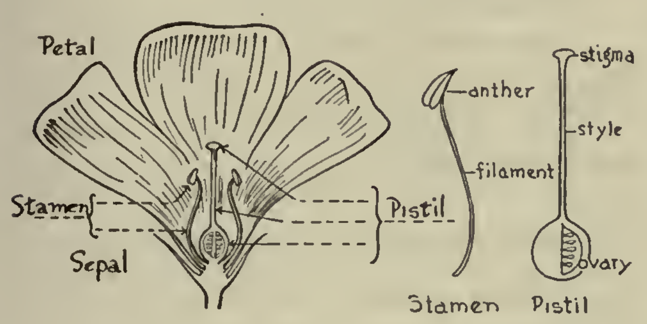


FIG. 368. STRUCTURE OF A TYPICAL FLOWER

In order that a seed may be formed from an egg cell, the egg must first be fertilized by a sperm. How can this happen when the egg cells are deep within the ovary at the base of the pistil? See Figure 369. On the top of the pistil is a structure called the stigma, which has a sticky surface. Pollen grains from stamens of the same flower or other flowers get upon the stigma. They burst open and grow down through the style into the ovary at the base of the pistil where the egg cells are located. Here the sperm unites with the egg. This is known as *the process of fertilization.*

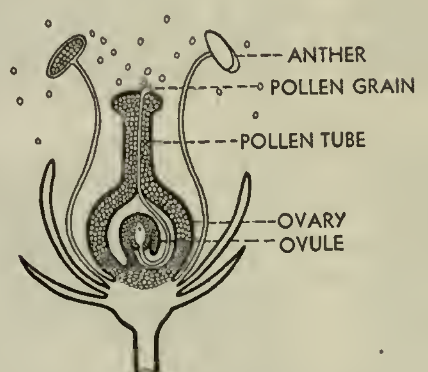


FIG. 369. POLLINATION OF A FLOWER

From the union of the nucleus of the egg cell with the nucleus of the sperm cell, a single cell is formed. Very soon after the union the new cell divides into two, then these two into four, and so on until the *embryo* or baby plant is formed within a seed. The seed, as we know from experience, shows no signs of life unless it is given certain conditions of water and temperature. Under these conditions the baby plant starts to grow and eventually produces flowers. These flowers may produce more seeds that in turn give rise to new plants.

What is pollination? The transfer of pollen from the stamens to the pistils is called pollination. In many flowers it is necessary that pollen come from a different flower. Many insects are attracted to flowers by their colors and odors. Some flowers produce *nectar,* a sweet fluid which insects use for food. Have you ever watched bees crawling around on flowers? They crawl down into the flower and become covered with the pollen. On their visit to another flower some of the pollen is brushed on to the stigma. Some birds are agents of pollination. Have you ever watched a humming bird in its visits to flowers? What is it after? Wind is also a carrier of pollen. Pollen grains are light and are picked up by wind, some of them falling on the stigmas of other flowers.

Do higher animals reproduce in a manner similar to flowering plants? They develop from female egg cells that have been fertilized by male sperm cells.

One of the surest signs of spring is the loud singing of frogs and toads, calling to their mates. The mother frog lays her eggs in the water, the tiny eggs being separated and surrounded by a large mass of transparent, jelly-like substance. The male frog deposits sperms over the eggs as the female lays them. The sperms swim in the water, penetrate the "jelly," and each unites with an egg, forming a new cell.

The formation of an adult frog from a fertilized egg is a wonderful process (Fig. 370). The fertilized egg cell divides into two cells, then into four, eight, sixteen, and so on, until a young tadpole is formed. The little tadpole wriggles out of the jelly surrounding it and lives on tiny plants in the water. During this stage its body is somewhat like that of a fish. Eventually the tadpole grows hind legs and then front legs and at the same time its tail is absorbed and disappears. Lungs develop in the chest cavity of the body, and it comes to the surface to breathe, and grows into an adult frog.

All the higher animals develop from fertilized eggs in a manner similar to the development of a frog. In birds and some reptiles the egg is protected by a hard shell, and the development of the young takes place within it. In mammals (man, dogs, horses, etc.) the fertilized eggs are retained in the body of the mother, where they grow until the young are ready to be born.

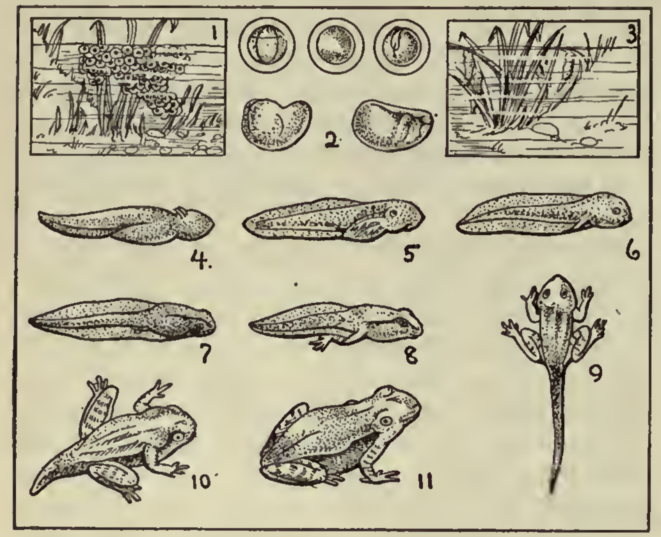


FIG. 370. LIFE HISTORY OF A FROG

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chaps. 29-32
Hunter and Whitman, *My Own Science Problems*, Unit 10; *Science in Our World of Progress*, Unit 14
Powers, Neuner, and Bruner, *The World around Us*, Units 2 and 8; *This Changing World*, Chap. 21
Watkins and Bedell, *General Science for Today*, Chap. 27
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 9
Wood and Carpenter, *Our Environment: How We Use and Control It*, Unit 8

Special references

Atwood and Heiss, *Educational Biology*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A clear understanding of the conception that all living things come from living things.
2. A knowledge of how simple one-celled animals and plants reproduce.
3. A knowledge of how flowering plants reproduce.
4. An understanding of how higher animals, such as frogs and birds, reproduce.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Is the statement that all life comes from life true, partly true, or false?
2. How do one-celled organisms such as bacteria reproduce?
3. The organs of reproduction of a plant are in the ____.
4. The parts of flowers which attract insects to them are called ____.
5. The transfer of pollen from anther to stigma of flowers is called ____.
6. The embryo of the new plant is contained in the ____.
7. Make a diagram of a flower and label the following parts: sepal, petal, stamen, pistil, ovary, anther, stigma, ovule.
8. What parts of a flower are necessary for reproduction?
9. What part do bees and other insects play in the reproduction of many flowering plants?
10. When frogs reproduce, a cell called the ____ unites with a cell called the ____. This process is called ____.

TOPIC 4. IMPROVEMENT OF LIVING THINGS

SUGGESTED PROBLEMS AND QUESTIONS

1. Are any two living things exactly alike? Explain the term *variation* as it is applied to living things.
2. Why do you resemble your parents?
3. Who was Gregor Mendel? For what is he noted?
4. Can mankind be improved?
5. Have animals been improved by man?
6. Have plants been improved by man?
7. What was the work of Luther Burbank?

SUGGESTIONS AND HELPS FOR STUDY

1. This is an important topic. The improvement of living things adds greatly to the comfort, happiness, and progress of man. Gather all the scientific knowledge you can find relating to the problem in this topic.

2. Study carefully the meaning of the scientific terms *heredity* and *variation*.

3. A study of the experiments by Gregor Mendel will show you how carefully a scientist works.

4. A study of the achievements of Luther Burbank will show you how scientific knowledge can be applied to produce practical and beneficial results to mankind.

5. Society is becoming greatly interested in applying scientific knowledge to the improvement of man. Find out the conditions in human society that need improvement and the ways by which this improvement can be made.

INVESTIGATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Activity 143. How do living things vary?

Collect a hundred leaves from a tree. Are any two exactly alike?

[1] See workbook, p. 83.

Make a study of the heights and weights of the members of your class. How do they vary?

Activity 144. What indications of heredity can you find in your own family?

Study the members of your family. In what ways do they resemble each other? How do they differ? How do your own characteristics compare with those of your parents? Record your observations.

Activity 145. What were the original sources of our cultivated plants and domesticated animals?

Answer the question in your notebook.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Are any two living things exactly alike? The living matter of all plants and animals is protoplasm. Protoplasm from all sources is similar in composition, yet there are probably as many different kinds of protoplasm as there are living things. The protoplasm of a hen's egg develops into a chicken, never into a rose bush or a robin. The protoplasm of a grain of wheat develops only into a wheat plant, never into an elephant or an apple tree.

Offspring resemble their parents in structure, form, and appearance. They are born with characteristics or qualities which a parent or some more distant ancestors had. The tendency of living things to resemble their ancestors is called *heredity;* heredity may be defined as the transmission of traits or characteristics from parent to offspring.

All the individuals of a particular group of living things are much alike. Dogs resemble dogs. Potato plants resemble potato plants. There is no difficulty in recognizing human beings because all human beings resemble each other. Yet no two individuals are ever exactly alike. Every human being resembles other human beings more than he resembles any other animal, but each human being is different in some way from all the others. It is believed that no two living things are ever exactly alike. Thus we discover that offspring generally resemble their parents, but they are also different from their parents. Why is this?

Environment is one cause of variation. It is perhaps the most common and obvious cause, especially in plant life. Differences in temperature, weather conditions, water supply, and soil influence the growth of common plants. Plants that grow at the timber line near mountain tops are stunted and slow to flower compared with similar plants at lower elevations. Seeds from the same parent plants sometimes produce better crops on one field than on another because of different soil conditions. We are familiar with the effects of too much or too little water on plants.

The development of animals also is influenced by conditions of temperature, food, light, and water. Cer-

FIG. 371. INFLUENCE OF HEREDITY

The photographs in the upper row show three generations of a defective strain. The lower photographs show the desirable inheritance of another family.

tain fish in dark caves are blind. The lizards and spiders of the famous Mammoth Cave are colorless. Among honeybees an egg may develop into a worker or a queen, depending upon the food the larva receives. Conditions of the environment also affect human beings. A lack of vitamins in food produces deformities of the body and certain diseases. A lack of iodine may retard physical and mental development. By education and practice one may develop habits and skills that are not found in an uneducated person. Too much food makes many people fat.

Why do you resemble your parents? Many traits appear generation after generation in living things regardless of a changing environment. Healthy cows that produce a large quantity of milk are selected to be mothers rather than cows that give only a small quantity because they transmit this trait to their offspring. For hatching purposes chicken raisers use eggs from hens that lay over 200 eggs a year, for egg-laying ability seems to be a hereditary trait. Differences are found among plants because they come from different stocks. Some cotton plants produce short fibers while others produce long fibers. Some corn plants produce long ears of corn, others short ears; some corn plants produce white grains on the ear, whereas others produce yellow or red grains, depending upon their particular variety. These traits may appear generation after generation even though environment or outward conditions change.

Heredity operates in man just as it does in other animals and in plants. We commonly observe, and hear people discuss, resemblances between parents and their children and between brothers and sisters. These common observations have been confirmed by scientific studies. Certain selected human traits such as color of hair and eyes, skin color, temperament, and intelligence have been traced through many generations. Heredity operates according to law and order.

Who was Gregor Mendel and for what is he noted? Gregor Mendel, an Austrian monk, discovered in 1866 that heredity operates under very definite laws. The principles of heredity that he discovered were forgotten until about 1900, when they were rediscovered by several other investigators. Since 1900 many experiments on heredity have been carried on, and it is believed that all kinds of physical and mental traits are transmitted from generation to generation.

Two families are commonly cited as examples of heredity. Jonathan Edwards, an eminent man, lived in New England during colonial times. In the year 1900 records of 1,394 of his descendants were studied. The tabulated facts that follow show the outstanding achievements of this notable family.

295 college graduates
13 college presidents
100 clergymen, missionaries, or theological professors
100 lawyers
30 judges
80 public officials
65 college professors
60 physicians
75 officers of army and navy
60 prominent authors

Winship states that almost if not every department of social progress and of public weal has felt the impulse of this healthy, long-lived family. It is not known that any of them was ever convicted of a crime.

A striking contrast to the Edwards family is furnished by the Jukes family. Max Jukes, a lazy and degenerate backwoodsman who lived in the state of New York, was the founder of the Jukes family of defectives, of which about twelve hundred descendants have been traced. It includes:

310 professional paupers
300 deaths in infancy
400 physical wrecks from debauchery
60 habitual thieves
50 immoral women
7 murderers
130 other criminals

At the time this record was made this family had already cost the state of New York $1,250,000. All this crime, immorality, and expense to the state might have been avoided if the original ancestor had been prevented from producing offspring.

Can mankind be improved? What a person is or becomes is determined by the influences of three great factors: (1) *heredity* or the characteristics transmitted to him by his ancestors, (2) *environment* or his surroundings, and (3) *training* or what he does. These three factors may be represented in the form of a triangle (see Fig. 372). Heredity is made the base of the triangle because an individual cannot change his heredity. Environment and training, the two sides of the triangle, may be modified with resulting changes in the individual.

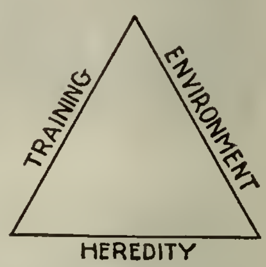


FIG. 372

In the United States today there are hundreds of thousands of men and women with serious physical and mental defects. Many of these defects are hereditary. More than half of the cases of feeble-mindedness are believed to be hereditary. Crime, immorality, pov-

erty, and alcoholism are closely associated with feeble-mindedness. It is believed that at least ten per cent of feeble-minded persons possess vicious tendencies and that all feeble-minded persons lack self control. When feeble-minded marry feeble-minded, as they commonly do, the children are feeble-minded.

International News Photos

FIG. 373. CONTRAST BETWEEN A TYPICAL NEW YORK TENEMENT AND A MODEL TENEMENT DWELLING

Since heredity is such an important factor, it is important that we consider the part it plays in the lives of people and in its effect on human society. The science of improving the heredity of future generations, either physically or mentally, is called *eugenics*. Leaders in the field of eugenics suggest the following methods for reducing the number of defectives:

1. Keeping defectives in institutions and preventing them from producing another generation like themselves. At present only about ten per cent of our defectives are in institutions.

2. Making and enforcing strict immigration laws to keep out defectives and relatives of defectives.

3. Revising marriage laws. A few states now require physical and mental examinations of the applicants before a marriage license is issued.

4. Educating the public concerning the principles of eugenics.

The health, happiness, and achievements of people are affected by their living conditions. Our homes today are better lighted, heated, and ventilated than those of a few years ago. In the crowded districts of our large cities many people are still living in poorly built tenement houses, but these conditions are being remedied gradually.

FIG. 374. CONTRAST BETWEEN UNSANITARY AND SANITARY DRINKING SERVICE IN SCHOOLS

Great progress has been made in our schools. The school house of a generation ago was often poorly ventilated and imperfectly lighted. The pupils worked on unsanitary slates and drank from the same drinking cups or dippers. Today our schools are clean and sanitary. Periodic medical examinations of school children are maintained in most school systems. These examinations show that many children are suffering from adenoids, diseased tonsils, decayed teeth, defective eyesight, or poor hearing. These conditions should be corrected while the child is young in order that he may get the best from his schooling. Sometimes children who are backward are able to do good school work after these defects are remedied.

The working conditions in factories are better than they were formerly. Child labor is generally prohibited by law. More and more industrial organizations are providing shorter working days, thus providing more hours of recreation for the workman.

Sanitary conditions in cities are greatly improved. We have our city and state boards of health to look after the health and recreation problems affecting the entire community. In addition, the United States Pub-

lic Health Service and many private agencies are at work helping to make better living conditions for all people.

What is your community doing to provide better living conditions for its citizens?

The achievements of people are not transmitted to their offspring by heredity. We are not born with the ability to read, write, do arithmetic problems, or speak English. Each person must learn to do these things by application and hard work. In other words, education must begin all over again with each generation. For this reason, schools will probably always be the most important of all our social institutions. Schools help us to become intelligent citizens.

Every trait or characteristic an individual possesses is either *inherited* or *acquired*. For a long time it was thought that the traits we acquire during a lifetime affect the next generation. We now know that acquired characteristics are not inherited. Acquired characteristics affect only the persons who have acquired them.

U. S. Dept. of Agriculture

FIG. 375. OUR DOMESTIC PIGS HAVE BEEN DEVELOPED FROM A SMALL WILD FORM

Germ diseases are not inherited. Germs are tiny microscopic plants or animals present in our environment. To become afflicted with a germ disease a person must first come into contact with the germ which causes the disease. However, a person may be born with a poor resistance to certain germ diseases. This is believed to be true for tuberculosis and cancer. Certain families seem to possess less resistance to these diseases than other families. Some organic diseases, that is, diseases not caused by germs, such as diabetes, St. Vitus's dance, and pernicious anemia, and the tendency toward bronchial asthma, certain forms of rheumatism, gout, and goitre may also be inherited.

Feeble-mindedness, epilepsy, and certain forms of insanity are inherited. There are a number of different kinds of insanity; how many has not yet been determined. Some forms are acquired; others are inherited. Possibly as many as fifty per cent of the cases of insanity are directly or indirectly due to heredity.

Deafness and blindness may be either acquired or inherited.

Have animals been improved by man? The improvement of plants and animals is made possible because of our knowledge of heredity and variation. Sometime during the development of our civilization man began the domestication of horses, cattle, sheep, and other animals. The strongest and best of the young were raised for breeding purposes, and in this way man aided nature in producing better stock. All our domesticated dogs are descended from the wolf, but the continual breeding for certain desired traits has resulted in many varieties. Man has changed the horse by breeding for desired characteristics so that today we have race horses, trotters, draft horses, and coach horses. In a similar manner all of our domesticated animals have been tremendously changed by controlled breeding since they were first captured in the wild state. Today every successful farmer knows that the best results are obtained only from good stock and that to produce the best it is necessary to breed from the best.

FIG. 376. ALL OUR DOMESTICATED DOGS MAY HAVE DESCENDED FROM THE WOLF

It is not unusual for thousands of dollars to be paid for cows with exceptional records and good ancestry. Certain championship cattle have sold for more than $50,000. There is, however, much poor stock in this country. "Good judges believe that in the entire country one fourth of the cows kept for milk do not pay for their cost of keeping, and nearly a fourth more fail to yield an annual profit. As a matter of ordinary business prudence and a condition essential to best results, every dairyman should study the individuality of his cows, keep a sufficient record of quantity and quality of milk produced, know approxi-

mately the cost of production, and systematically weed out his herd."[1]

Scientific poultry raising results in marked success. A record is kept of the eggs laid by each hen. This is done by trap-nesting. The nests are of such a design that only one hen can enter a nest at a time and she cannot leave until released. Each hen has a numbered tag on her leg and every egg she lays is credited to her. By breeding only from the best layers we can increase the average number of eggs laid by a flock.

FIG. 377. EDISON'S GOLDEN ROD This giant plant was developed by crossing and selection from a common variety.

Have plants been improved by man? All of our domesticated plants are descendants of wild ancestors. By taking advantage of variations and selecting and cross-breeding different types of plants, we have kept desirable traits. Sometimes plants quite different from their parents suddenly appear in nature. Our seedless oranges originated in this way. Some one discovered two orange trees growing in South America that bore seedless oranges. These plants were later removed to California, where the buds were grafted on trees that produced oranges with seeds.

What was the work of Luther Burbank? As a creator of new forms of plant life in this country, Luther Burbank (1849-1926) won for himself much recognition as a benefactor of man. Most of his new and improved plant forms were developed on his experimental farm at Santa Rosa, California. He used the methods of *selection* and *crossing* to obtain his wonderful new plants. He was a genius at selecting plants of near relationship showing the traits he wished to establish and perpetuate. He would cover the flower of a certain plant and remove the stamens before pollen developed. At the proper time he would put on the stigma of this flower some pollen from another plant possessing traits he wished to establish in the first plant. In this way he produced many new varieties. These methods of plant breeding are now used in experimental breeding stations operated by agricultural colleges, state departments of agriculture, and the United States Department of Agriculture.

Burbank produced a great many new flowers, fruits, and vegetables. He crossed a cream-colored berry with a blackberry and by selecting for several generations succeeded in obtaining a large white blackberry (Fig. 378). He crossed the apricot with the plum and developed a new fruit called the plumcot. By his genius a cactus of Arizona has been rid of its thorns and is now used as a food for cattle. He produced walnut trees that grew seven feet in one year, whereas ordinary walnut trees grow less than an inch a year. These are a few of Burbank's achievements. Consult one of the special references for more details of his life.

FIG. 378. WHITE BLACKBERRIES

Summary. The purpose of this study is to acquaint you with the factors that influence the lives of all living things. Read carefully the following statements which summarize the main ideas developed in this topic.

1. Offspring resemble their parents because they have received traits and characteristics from them. This is called heredity.

2. Offspring are never exactly like their parents. This is called variation. Variation is due to (1) environment and (2) the fact that the offspring receives traits from two parents that are not alike; hence the offspring cannot be like either parent.

3. Man improves plants and animals by selection and controlled breeding.

4. Heredity operates by law, and both good and bad traits are inherited.

5. Heredity, environment, and training are the important factors in the life and progress of man.

6. It is possible to improve man by weeding out unfit people, by improving the environment, and by creating better facilities for education.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 32

Hunter and Whitman, *Science in Our World of Progress*, Unit 14

Powers, Neuner, and Bruner, *The World around Us*, Units 2 and 8; *Man's Control of His Environment*, Chaps. 1-3

Watkins and Bedell, *General Science for Today*, Chap. 31

Webb and Beauchamp, *Science by Observation and Experiment*, Unit 9

Wood and Carpenter, *Our Environment: How We Use and Control It*, Unit 8

[1] *Bulletin No. 55,* U. S. Department of Agriculture.

Special references

Jewett, *The Next Generation*
Downing, *The Third and Fourth Generation*
Luther Burbank Society, *Burbank, His Methods and Discoveries*
Harwood, *New Creations in Plant Life*
Burbank, *How Plants Are Trained to Work for Man*
Guyer, *Being Well-Born*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A thorough understanding of the scientific principles of variation and heredity.
2. How man improves plants and animals for his own benefit.
3. The contributions of Mendel and Burbank.
4. How heredity, environment, and training affect the lives of people.
5. How man can improve himself.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions..

1. The continuance from generation to generation of similar traits in living things is called ——.
2. Our laws of heredity were first discovered by ——.
3. Three new varieties of plants that Luther Burbank developed are ——.
4. Two methods employed by plant and animal breeders to improve life are ——.
5. Some conditions in my environment that are in need of improvement are ——.
6. Good and bad traits can be transmitted from parents to their offspring by ——.
7. Heredity in man works according to ——.
8. No two human beings in the world are exactly alike. Why is this so?
9. Write a paragraph explaining how the human race may be improved from generation to generation.
10. Offspring are never like their parents. This fact is expressed by the term ——.

SUPPLEMENTARY MATERIALS

Reading suggestions

De Kruif, *Microbe Hunters* (Harcourt)
De Kruif, *Hunger Fighters* (Harcourt)
Sanderson, *Insect Pests of Farm, Garden, and Orchard* (Wiley)
Mayne and Hatch, *High School Agriculture* (American Book)
Jordan, *The Heredity of Richard Roe* (Beacon Press)
Waldo, *Stories of Luther Burbank and His Plant School* (Scribner)
Wiggam, *Fruit of the Family Tree* (Bobbs)
Goddard, *The Kallikak Family* (Macmillan)
Bayne-Jones, *Man and Microbes* (Williams and Wilkins)
Fishbein, *Fads and Quackery in Healing* (Covici)
Flint and Metcalf, *Insects: Man's Chief Competitors* (Williams and Wilkins)
Haggard, *Devils, Drugs, and Doctors* (Harper)
Meyr, *Your Germs and Mine* (Doubleday)
Phillips, *Skin Deep: The Truth about Beauty Aids* (McLeod)
Zinsser, *Rats, Lice, and History* (Little)
Fishbein, *Shattering Health Superstitions* (Liveright)
Haggard, *What You Should Know about Health and Disease* (Harper)
Harrow, *Vitamins* (Dutton)
Hull, *Diseases Transmitted from Animals to Man* (Thomas)

Reports which may be prepared

1. The life of Louis Pasteur
2. Luther Burbank and his work
3. Koch and the discovery of tuberculosis
4. The work of Walter Reed and his associates in their investigations of yellow fever
5. The life and work of Edward Jenner
6. The proper care of milk
7. Colds and their causes
8. The mosquito and malarial fever
9. Beneficial bacteria and their work
10. The fly and its relation to disease
11. Patent medicines and quack doctors
12. Contributions of Gregor Mendel to our knowledge of heredity

Great scientists you should know about

1. Gregor Mendel
2. Luther Burbank
3. Dr. Walter Reed
4. Louis Pasteur
5. Robert Koch
6. Edward Jenner

Investigations and things to do

1. Make and use a fly trap.
2. Collect some frog's or toad's eggs and keep them in right condition for development. Observe the progress of their development and make a report of it.
3. Investigate reproduction in a flowering plant and report the differences between its method of reproduction and the process of reproduction of birds or frogs.
4. Make a careful study of your own environment. Compare it with a better and a poorer environment. What suggestions have you for the improvement of your own environment?
5. Investigate how vaccines and antitoxins were discovered. How are they prepared and used?
6. Investigate the best methods in use to destroy harmful insects.

UNIT XI. ELECTRICITY AND HOW WE USE IT

"Snap!" the switch is pushed and the room is flooded with light, the electric iron begins to heat, the motor whirs as it gains speed to turn the washer, sewing machine, or grinder. We step on the street car and in a little time we are whisked from one side of the city to the other. A few clicks of the telegraph and a message is sent with tremendous speed to the remotest corners of the globe. The receiver is taken from the hook and in a few moments one may be talking to Seattle, New York, or Galveston. A few careful manipulations of the dials of your radio and you hear the music of New York, Los Angeles, or Havana. What a wonderful thing electricity is and how dependent we are upon it for modern convenience and comfort!

Electricity has been known since the time of the Greeks, twenty-five hundred years ago. They observed that amber, called "electron" by them, when rubbed would pick up bits of paper or other light objects. Centuries later Gilbert called these mysterious things "electric." Today, thanks to modern scientific methods, we know more about electricity, but we are only beginning to understand what it really is.

It is seldom, unless we are "shocked," that we give any thought to the tremendous amount of energy that lies at our finger tips. Rarely do we marvel or wonder at the doings of this invisible but faithful servant. But take it away and we should be set back a hundred years in progress. For all the conveniences, not only of electricity but of all applied science, we are indebted to the past and obligated to the future. The modern servant, electricity, would not have been possible had not Gilbert, Franklin, Galvani, Volta, Davy, Oersted, Ampere, Ohm, Wheatstone, Faraday, Henry, Gramme, Maxwell, Kelvin, Morse, Bell, Edison, Marconi, Fleming, DeForest, and others spent years of thought and experimentation, often under great privation, to perfect its control.

Our obligation to the past is to know the great effort that has brought electricity to its present state of development. Our obligation to the future is twofold: first, to conserve the present supplies or natural sources of energy, that the future may benefit from them also; second, to push back the frontiers of knowledge that the mysteries of electricity may be better understood.

In the study of this unit we want you to learn how magnetism is related to electricity, how Faraday discovered a way to change mechanical energy to electrical energy, and how electricity is put to use in the home.

The exercises that follow should help you to see how much you know about the subject to be studied and should raise some questions in your mind that you will wish to answer through study.

What do you know about electricity?

1. Rub a hard rubber comb or fountain pen on the sleeve of a woolen coat or dress and explain what happens when the comb or pen is brought near bits of paper or cork.
2. Secure a steel needle and run it lengthwise through a cork. Float the needle and cork in a glass of water and bring a magnet near. Explain what happens. Stroke the point of the needle with the end of the magnet marked *S* and replace it on the water. Remove the magnet and explain what happens.
3. Examine the device which turns an electric washing machine or sewing machine. What is it called? How does electricity make it turn and do work?
4. Snap the electric switch in your room. Why does the light go out?
5. Examine an electric toaster. Why do the wires get hot?
6. Find the electric meter in your house and make a diagram sketch of every detail on the face, including the printing. Can you explain what the printing means and can you read the dials?

TOPIC 1. SOME WAYS OF SECURING ELECTRICAL ENERGY

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is electricity?**
2. **How may electricity be obtained by friction?**
3. **How is electrical energy secured from chemical energy?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems listed above and see if they are questions which you have wondered about or are interested in.

2. If you experiment with the simple voltaic cell or storage battery, be very careful not to get the sulphuric acid on your hands or clothing.

3. In the study of this topic you may meet the following words for the first time. Study them carefully and use them as frequently as possible in order that they may become a part of your vocabulary.

ammonium chloride—a salt-like substance which contains nitrogen, hydrogen, and chlorine and is used in dry cells.

atom—the smallest particle of an element.

cell—a single unit for producing electrical energy from chemical energy.
battery—a group of electric cells connected together.
electrify—to charge with electricity.
electron—a negative particle of electricity.
insulator—a non-conductor of electricity or heat.
lead peroxide—a chemical compound of lead and oxygen used on one of the plates of the storage battery.
molecule—the smallest bit of any substance which may still be recognized as that substance by its properties. For example, the smallest bit of wood which would still be called wood.
nucleus—the central part of the atom.
proton—a positively charged electrical particle in the nucleus of the atom.
static electricity—electric charges which are not in motion.
terminal—a binding post on an electric cell or battery.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 146. How may electricity be produced by rubbing?

Secure two toy rubber balloons, blow them up, and suspend them from a support. Rub a fountain pen or hard rubber comb with a piece of fur and bring it near one of the suspended balloons. Note what happens. Rub each balloon briskly with the fur and observe what happens. Bring your hand near one of the balloons. What do you observe? Rub a balloon with fur and bring near it a fountain pen also rubbed with fur. Observe the result. Rub one balloon with the fur; then rub a glass rod or dish briskly with a piece of silk and bring near the balloon. Record your results. If the materials are available, rub sealing wax, sulphur, and several metal rods with fur and bring them near a balloon which has been rubbed. Observe and record your results.

The balloon was (attracted, repelled) ____ by the fountain pen which had been rubbed with fur. When both balloons were rubbed they seemed to (attract, repel) ____ each other. When the hand is brought near a balloon which has been rubbed with fur, the balloon is (repelled, attracted) ____. A balloon rubbed with fur is (repelled, attracted) ____ by a fountain pen also rubbed with fur. A balloon rubbed with fur is (attracted, repelled) ____ by a glass rod rubbed with silk. Metal rods rubbed with fur (do, do not) ____ influence the balloon. Sealing wax and sulphur when rubbed with fur (attract, repel) ____ the balloon.

Experiment 147. How are dry cells constructed?

Remove the pasteboard containers from an old and a new dry cell and carefully study the condition of the zinc can in each one. Record any differences noted. With a saw cut lengthwise through the zinc can of the old cell and then push the sides of the cut apart. Carefully observe the inner construction of the cell, recording your notes in your notebook. Remove the carbon rod from the center of the cell and study it. What seems to be between the rod and the zinc can? Does the carbon rod touch the zinc?

The zinc of the old dry cell seemed to ____ while the new one was not. Inside the zinc can were several layers of ____.

[1] See workbook, p. 84.

The carbon rod and zinc can (were, were not) ____ in contact. The cell was sealed at the top with ____. Between the carbon rod and the zinc can there seemed to be a ____ substance which was ____ in color.

Experiment 148. How is a storage battery constructed and how does it work?

Secure two pieces of lead about an inch and a half wide and five inches long. Punch a hole through each piece with a nail and attach a copper wire by inserting it in the hole. Clean the plates with fine sandpaper or steel wool and place them in a solution of four parts water to one part concentrated sulphuric acid. *Be careful to pour the acid slowly into the water, and not to get any on your hands or clothing.* Attach the wires to an electric bell and note any results. Now connect three dry cells together in series, that is, from the carbon of one cell to the zinc of the next and so on (Fig. 379). Connect these cells to your storage cell and carefully observe what happens. After the storage cell has been charged for about ten minutes, disconnect the dry cells and again observe the lead plates. Note any change. Again attach the storage cell to the electric bell and observe results.

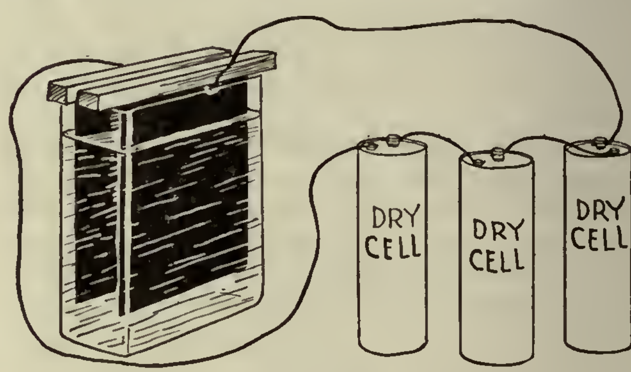


FIG. 379

Secure a worn-out storage battery from a garage and tear it to pieces. Compare the parts with your simple cell and find out wherein they differ.

When the cell was first connected with the bell it (did, did not) ____ ring. The plate of the storage cell connected to the carbon of the dry cell battery changed to a ____ color. A ____ was given off by the storage cell while it was charging. The lead plate connected to the zinc of the dry cell battery seemed (to, not to) ____ change in color. The ____ substance on the one plate probably came from the chemical action in the cell caused by the ____ from the dry cells flowing through it. When the storage cell was again connected to the electric bell, I found that the bell ____.

Explain below how the simple storage cell which you made is like a large storage battery and how it is different.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Study the operation of a simple voltaic cell.
2. Study the operation of an ammonium chloride cell.
3. Visit a storage battery service station and secure all the information possible about the testing, charging, and care of storage batteries.
4. Examine the storage battery on your car and, if possible, learn to test it.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is electricity? Electricity has been known for many centuries. Thales, an ancient Greek who lived 600 years before the birth of Christ, knew that when amber was rubbed, it would draw bits of light substances like paper and cork to it. In Greek the word for amber is *electron*, and so when it was later discovered that other things than amber when rubbed would also attract, people called the phenomenon "electric." Little was really understood about this peculiar attraction until about two hundred fifty years ago when men began to experiment with it and lay the foundations of modern electricity.

There are two types of electric charge. Early in the history of experimenting with electricity men discovered that there were two kinds and gave them the names of positive and negative. It became the custom to think of an ebonite rod which had been rubbed with fur or flannel as being negative and a glass rod rubbed with silk as being positive. Your experiment has taught you that if a negative electric charge is brought near a negative charge on a balloon they push apart or repel, but if a positive charge, like that of a glass rod which has been rubbed with silk, is brought near a negatively charged balloon they will draw together or attract.

Some substances conduct electricity while others do not. Copper and aluminum are used to carry the current in telephone and telegraph wires while glass, porcelain, hard rubber, cloth, and other like substances are used to insulate electric wires. Things like copper and aluminum which carry the electric current readily are called conductors, while substances like glass, rubber, and porcelain are called non-conductors or insulators.

How may electricity be obtained by friction? Although the action of like and unlike electrical charges has been known for many years, it remained for modern scientists to discover the reason back of it. Within the past fifty years scientists have come to believe that everything in the universe is made up of tiny particles of electricity, so small that not even the most powerful microscope could show them. Strange to say, there are two kinds of these little particles, one of which is negative and the other, positive. The negative particles are called *electrons* and the positive particles, *protons*. In conductors many of the electrons are continually freeing themselves from some atoms and entering others; in non-conductors there seem to be very few of the free electrons.

An interesting thing about these electrical particles of which everything is made is that the unlike particles attract one another while the like particles repel. That is, protons attract electrons and repel protons, while electrons attract protons and repel electrons.

All things are made of electrons and protons. The stars, the moon, the earth, stone, wood, paper, dirt, dust, metals, amber, glass, cloth, air, water, food, even the flesh of the human body is built up of these tiny electrical particles. It would seem that everything would have an electric charge, but that is not true, for bodies are positively or negatively charged only when there are more protons than electrons on them or the reverse. When there are the same number of electrons as protons in a body, every proton is balanced by an electron, and the body is neutral or uncharged. If there are more protons than electrons, the body is positively charged, while if there are more electrons it is negatively charged.

When you rubbed the balloon and fountain pen with fur you rubbed some of the tiny electrons from the fur over to the balloon and pen. When the glass was rubbed with silk some of the electrons were rubbed off on the silk, leaving the glass positively charged. It is easy to make electrons stay on glass, rubber, silk, porcelain, wax, or other non-conductors, but as your experiment taught you, they cannot be made to stay on iron or other metals that may be rubbed. The electrons flow away through conductors. An electric current flowing through a wire, a light, or a toaster is just millions and millions of these tiny electrons streaming past.

Man has learned how to make electrons go where he wishes and perform at his command. This has made possible all the modern developments of electricity, such as heating devices, motors, telephones, telegraph, radio, and television.

Exercise. *From your study of this topic thus far, infer a cause for each of the following:*

1. *Your hair will follow a comb which is drawn through it on a cold, dry day.*
2. *Sparks may be drawn from a cat's fur by rubbing it.*
3. *A severe shock is often experienced after one walks over a rug and then touches a radiator or waterpipe.*
4. *Sometimes one gets a slight shock when a metal filling in a tooth is touched with a silver fork or spoon.*

Lightning is a stream of electrons under a very high voltage or electrical pressure, flowing from a cloud either to the earth or to another cloud. It is the result of the accumulation of static electric charges in the clouds which scientists believe are caused by the friction of air currents against the clouds. As these charges increase, the electrical pressure rises often to several million volts, and then just as water from a bursting dam will run to lower levels, the electrons from a charged cloud rush to the earth or to another

cloud that may be at a lower pressure or voltage.

When lightning strikes it usually hits a tree, telephone pole, or building that is somewhat higher than other objects in the immediate vicinity. It has been proved, though many persons doubt it, that lightning may strike in the same place time after time.

Many facts about the behavior of lightning have been learned by observation and careful study. If one is out in a thunderstorm it is unwise to seek shelter under a tree that stands by itself away from other trees, and one should stay well away from telephone and telegraph poles. If you are indoors during an electric storm, keep away from objects that may have a connection to the ground, such as the telephone, radio, radiators, sinks, and the like.

Lightning rods are used to protect buildings from being struck by lightning. The lightning rods are connected to metal plates in the ground by heavy conducting cables. If lightning should strike a house equipped with rods, the electricity most likely would be conducted to the ground by the cables and would do no harm to the building.

Exercise. *Would a tall chimney made of brick or one made of iron be more likely to be struck by lightning? Explain.*

Exercise. *What inference can be drawn from the fact that the cables from lightning rods on buildings are attached to plates buried deep in the earth where the soil is moist, rather than near the surface where the soil is more likely to be dry?*

Taylor Instrument Company

FIG. 380. LIGHTNING FLASH

Courtesy Smithsonian Institution

FIG. 381. EARLY VOLTAIC PILE

How is electrical energy obtained from chemical energy? About 1785 Luigi Galvani, an Italian scientist whose wife was in poor health, secured some frogs from which frog-leg soup was to be prepared for her. While he was skinning them his knife happened to touch a metal clamp with which they were being held and he was very much surprised to notice a twitching in the legs. He repeated the experiment many times and finally wrote a paper on what he called "animal electricity."

About ten years later Alessandro Volta, another Italian, after reading of Galvani's experiments thought that the electricity had come from the unlike metals touching the moist flesh of the frog. He set up an experiment in which he had plates of zinc and silver separated by cloth pads moistened in salt water and was able to get electricity from them. This was the first electric battery and was described by Volta in a paper which he wrote. Figure 381 shows a photograph of an early *voltaic pile,* as it was called.

Volta discovered that he could get electrical energy from chemical energy whenever two unlike metals were placed in a solution, provided one of the metals was acted upon more rapidly by the solution. This has become one of the most important modern methods of securing electricity and has resulted in many different types of electric batteries, among which are the wet cell, the dry cell, and the storage battery.

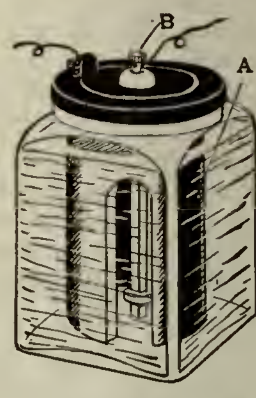


FIG. 382. AMMONIUM CHLORIDE CELL

The wet cell or ammonium chloride cell is shown in Figure 382. It has a cylinder of carbon *A* and a rod of zinc *B* dipping into a solution of ammonium chloride, commonly called sal ammoniac. In this cell the zinc rod is acted upon and eaten away by the solution and is therefore the negative plate, while the carbon cylinder is the positive plate. These cells are not now used to any great extent, but formerly found wide use for ringing doorbells. We study this cell because it is in many ways like the dry cell which is commonly used.

The dry cell has come to be one of the most common sources of electricity because it is easy to handle and takes up a very small space. The dry cell is really dry only from a point of view of handling it, for it supplies electricity because it has two unlike plates touching a chemical paste which acts upon one of the plates more than upon the other. The cross-section drawing in Figure 383 shows the construction of the dry cell. The zinc can *A* acts both as a container to hold the rest of the cell and as a negative plate. Inside the zinc can is placed a layer of blotting paper *D* which has been soaked in sal ammoniac. The carbon rod *B* extends down through the center of the cell almost to the bottom. Between the carbon rod and

the blotting paper is placed a damp paste of sal ammoniac, powdered carbon, and other substances. The cell is tightly sealed with a layer of pitch shown at *E*. The chemical action takes place as in the wet cell between the zinc can and the sal-ammoniac paste. The zinc is gradually eaten away until it breaks through. When this happens the moisture in the cell evaporates, drying out the paste, and the cell is no longer usable. Old dry cells can sometimes be restored by punching holes through the zinc, soaking in water, and resealing the holes with wax.

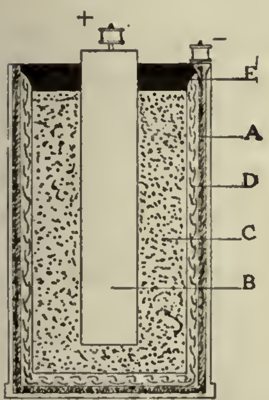


FIG. 383. CROSS SECTION OF DRY CELL

Dry cells are used in flashlights, radios, and many places where electric current is needed.

Exercise. *A flashlight using three small dry cells was found not to light. The cells, which had slipped into the case freely when new, were now stuck and difficult to remove. When removed they were found to have expanded and to be covered with a white substance. Infer a probable cause for the failure of the light to work.*

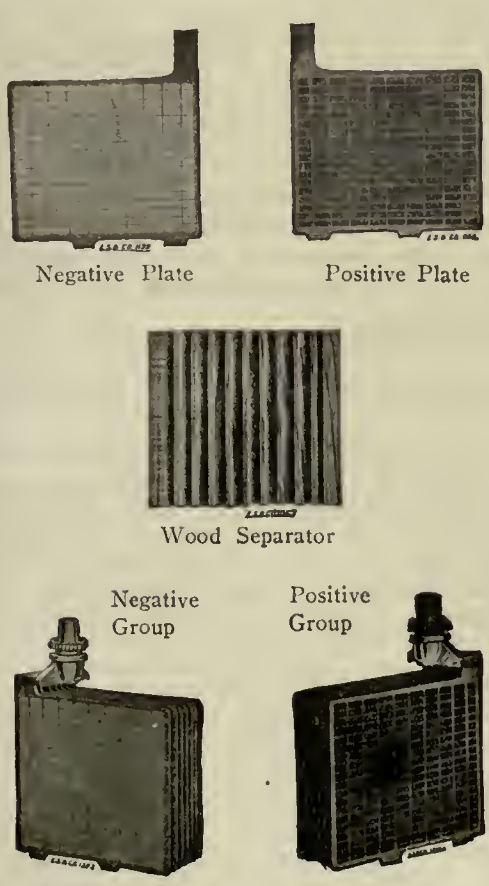


FIG. 384. PARTS OF A STORAGE BATTERY

The storage battery is a common source of electrical energy. The development of the automobile and radio has made the storage battery a commonplace device in the experience of many boys and girls. Because it is an important part of the automobile and demands careful use and attention, everyone should know about it.

The storage battery stores chemical energy. Many persons believe that the storage battery is a sort of tank or reservoir in which electricity is stored for future use. This, however, is not true, for the storage battery gets its electrical energy from chemical energy in exactly the same way that the wet cell or the dry cell does. It is different from these only in that its chemical energy can be restored when it has been used up while this is impossible in the wet cell and the dry cell.

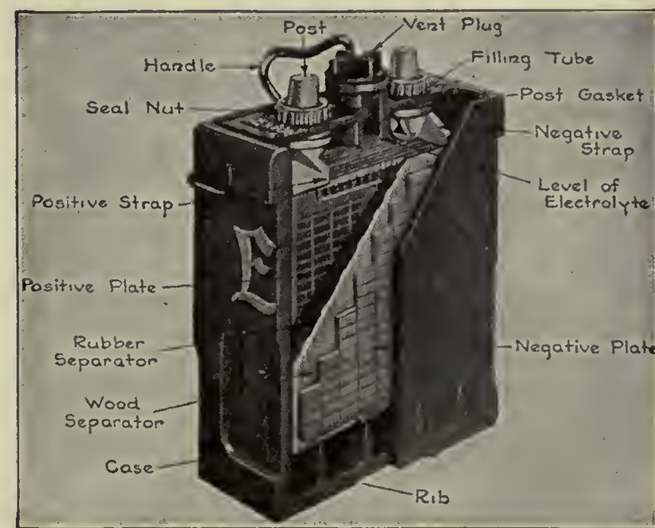


FIG. 385. CROSS SECTION OF A STORAGE BATTERY

Your experiment has taught you that if two lead plates are placed in a solution of sulphuric acid and a current of electricity is run into the cell from dry cells or other source, a chemical action goes on in the cell as shown by the gas which is given off and also by the change to a deep brown color of one of the plates. This is called *charging* the cell, and the important thing that is happening is that the plates are being made unlike by the chemical action. The brown substance is a compound of lead and oxygen, *lead peroxide.*

When the source of current is taken away, the storage battery will give electrical energy because it has two unlike plates, one of lead and one of lead peroxide, dipping into a solution of sulphuric acid. When the cell is delivering electricity the lead peroxide plate is the positive and the pure lead plate the negative. In the commercial storage battery (see

Fig. 385) the lead peroxide is not built up on a pure lead plate as you made it in your experiment, but is placed in the cell when it is manufactured.

The storage battery requires considerable attention, and certain things in its care are very important. The following rules will be helpful if you ever have to care for one.

a. Have each cell of the battery tested at least once in three weeks at a battery service station.

b. See that the plates of the cells are kept covered with solution. Only pure distilled water should be added.

c. Keep all battery connections clean.

d. Have the battery charged when the tests show that recharging is needed.

Exercise. *John drove his father's car to the service station to have the storage battery tested. The attendant found the plates only half covered with water, but told John that he would have to return later in the day as he had just used his last distilled water in another battery. As John had learned at school that it was bad for the battery to leave the plates exposed, he drove home and drew some water from the city water tap and filled the cells of the battery. A few days later John's father had to buy a new battery. Infer a reason and establish a probable cause for the old battery's failing.*

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chaps. 21-22

Clement, Collister, and Thurston, *Our Surroundings,* Chap. 15

Hunter and Whitman, *My Own Science Problems,* Unit 7; *Science in Our World of Progress,* Unit 7; *Science in Our Social Life,* Unit 7

Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 23

Pieper and Beauchamp, *Everyday Problems in Science,* Unit 14

Powers, Neuner, and Bruner, *Man's Control of His Environment,* Unit 5

Skilling, *Tours through the World of Science,* Tour 10

Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 17

Watkins and Bedell, *General Science for Today,* Chap. 23

Webb and Beauchamp, *Science by Observation and Experiment,* Unit 5 (part)

Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 9

Special references

Lunt, *Everyday Electricity*

Meister, *Magnetism and Electricity*

Darrow, *Masters of Science and Invention*

Morgan, *The Boy Electrician*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the early history of electricity.
2. A knowledge of the construction, operation, care, and uses of the dry cell and the storage battery.
3. Skill in handling and connecting various types of electric cells.
4. Skill in determining the condition of a storage battery.
5. A concept of electricity as a form of energy.

TEST OF MASTERY OF TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The solution used in the voltaic cell is ____.
2. All matter is built of (atoms, molecules) ____ which are made of ____.
3. ____ are negative particles of electricity.
4. The ____ plate of a cell is always acted upon more by the solution than the ____ plate.
5. When rubber is rubbed with wool it is charged ____.
6. In the dry cell pictured in Figure 383, the part shown at *A* is made of ____.
7. The part shown at *C* contains ____.
8. The part shown at *B* is the ____ plate and is made of ____.
9. When a glass rod is rubbed with silk it is charged ____.
10. The smallest particles of ____ electricity are called protons.
11. The dry cell has blotting paper in it to ____.
12. A ____ is used to test the charge in a storage battery.
13. ____ is the solution used in a storage battery.
14. The positive plate of a storage battery is made of ____.
15. The negative plate of a storage battery is made of ____.
16. Storage batteries must have ____ added to them frequently.
17. Write a summary of your understanding of each of the three problems listed at the beginning of this topic.
18. Lightning is electrical ____ that usually take place from ____ to the ____ or from cloud to ____.
19. City homes are less frequently struck by lightning than country homes. How many reasons for this fact can you suggest as possible causes?

TOPIC 2. SECURING ELECTRICAL ENERGY FROM MAGNETS AND ELECTROMAGNETS

SUGGESTED PROBLEMS AND QUESTIONS

1. **Why do magnets pull some things to them?**
2. **Why does a compass point northward?**
3. **What are electromagnets, and for what are they used?**

SUGGESTIONS AND HELPS FOR STUDY

1. As magnets and electromagnets are used in a great many common devices such as telephone receivers, electric bells, and telegraphs, they should be thoroughly understood.

2. The following new words and phrases may be found in this study:

electromagnet—a coil of wire surrounding an iron core which is magnetized only when a current of electricity flows through the coil.

magnetic field—the space about a magnet which is influenced by the magnet.

magnetic lines of force—the invisible lines of magnetic energy which make up the magnetic field; they may be mapped with iron filings.

magnetic pole—the place on a magnet where the magnetism seems to be concentrated.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 149. What things will magnets pick up?

Assemble a horseshoe or bar magnet and several small articles made of the following substances: copper, iron, glass, rubber, nickel, paper, silver, zinc, carbon, lead, brass, steel, and aluminum. By bringing the magnet near each one of these in turn, classify them in two groups, magnetic substances and non-magnetic substances. Record your results.

Experiment 150. Why do magnets draw some things to them?

Carefully study a bar magnet and observe any markings on it. Suspend a bar magnet horizontally by a string attached at its center. Bring the end marked *N* of another magnet near the *N* end of the original magnet. Bring the end marked *S* near the end marked *S* of the suspended magnet. Record your results. Bring the *N* end of the magnet near the end marked *S* on the suspended magnet. Repeat, using the other ends of the magnets.

Place a bar magnet on the table and cover with a clean sheet of paper. Sprinkle iron filings over the paper and tap lightly with your pencil. In your notebook draw the results of your experiment. In a similar way map two *N* poles placed near each other; map two unlike poles placed near each other. Draw the results in your notebook and complete the following statements.

The letter ____ appears at one end of a bar magnet while ____ appears at the other end. These letters refer to the ____ pole and the ____ pole. Magnetic poles which are ____ seem to push apart or repel, while poles which are ____ seem to attract.

[1] See workbook, p. 87.

Experiment 151. How does a compass work?

Bring a magnet near a compass needle and observe what happens. Bring the north pole of the magnet, and then the south pole, near the compass. Place the bar magnet on the table with its *N* pole pointing north. Hold the compass about four inches from the magnet above its center. Which way is the *N* of the compass pointing? Now reverse the magnet and again hold the compass above the magnet. What change is noted? In your notebook write the notes of your experiment and complete the following statements.

The compass needle is a ____ and has ____ the same as other magnets have. When the north pole of a magnet is brought near the needle, the ____ end of the compass is attracted; the ____ end is attracted by the south end of the magnet. A compass seems to have its ____ magnetic pole attracted toward the north and its ____ magnetic pole toward the south. This would seem to show that the magnetic attraction from the north is of a ____ polarity, and that from the south is of a ____ polarity.

Experiment 152. What are electromagnets and how do they work?

Secure a large nail or bolt, about four feet of bell wire, two dry cells, a compass, and a box of iron tacks or small brads. Wind about three feet of wire on the nail, leaving some at each end. Bring the coil and nail near the compass; also try to pick up some of the tacks. Attach the ends of the coil to one dry cell. Bring each end of the nail near the compass. Change the wires at the dry cell and repeat with the compass. Record the results in your notebook. Bring the magnet near the tacks. Break the connection to the cell while the tacks are pulled to the magnet. Results? Count the number of tacks which you can pick up. Wind another foot of wire on the nail and see how many tacks can be picked up. Add another cell and see how many tacks can be picked up.

In your notebook complete the following statements.

A coil of wire wound on an iron core and attached to a dry cell is a magnet when ____. When the dry cell is disconnected the electromagnet ____ its magnetism. One end of the magnet is a ____ pole and the other a ____ pole. When the direction of the current through the coil is reversed by changing the wires at the dry cell, the poles of the magnet are ____. An electromagnet can be made stronger by ____ or by ____.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

Why do magnets pull some things to them? Magnets have been known for many centuries. Long ago, even before the birth of Christ, it was known that a certain kind of iron ore existed in Asia Minor which would attract small bits of iron to it. This ore came to be known as magnetic ore. Even before that time

it is thought that the ancient Chinese used long pieces of such ore in guiding journeys on land and sea because of the fact that it arranges itself in a general north and south direction when suspended. The Greeks also knew of this property of bars of magnetic iron ore, which they called lodestones or pointing stones. Today we speak of this substance as a natural magnet.

Only a few substances are magnetic. Since ancient times it has been discovered that not only iron, but also steel, nickel, and cobalt, a substance closely resembling nickel, are magnetic. These substances can be picked up with a magnet, but all other things except one or two alloys[1] are not influenced when brought near a magnetic field.

In your experiment you discovered that a magnet could influence a compass or another magnet without touching it. A strong magnet will cause tacks and other bits of iron to jump from a table top to meet it. This action shows that a magnet influences things at a distance. Your experiment in which you sprinkled iron filings over a magnet shows the same quality. The space about a magnet is spoken of as a *magnetic field* and is filled with *lines of force.* The iron filings arranged themselves along these lines of force. The stronger a magnet, the greater number of lines of force it will have in its magnetic field.

The magnetism in a magnet seems to be concentrated in two places near the ends, which are called its *poles.* A bar magnet has a pole near each of its ends, one of which points northward and the other southward if the bar is suspended. They are called the north-seeking and south-seeking poles of the magnet. Your experiment taught you a very important law of magnetism that like magnetic poles push apart or repel and unlike magnetic poles attract each other.

Exercise. *Plan an experiment to test whether magnets have more than two poles, that is, whether there are other points where the magnetism seems to be concentrated. Iron nails or steel needles or old bar magnets may be used.*

Exercise. *With a compass test the iron of a bridge. It is magnetized? Infer a cause for this. Test an iron fence post with a compass. Is the top magnetized? How? Is the bottom magnetized? What is its polarity? Suggest a possible theory to account for this. Suggestion: How does the earth's magnetic field influence bodies in it that are magnetic? Are all iron poles magnetized the same? Suggest an experiment with a small iron bar and a magnet to test your theory. Try it out.*

Refer to the drawings which you made in your experiment and again see how the lines of force appeared when like poles and when unlike poles were placed together. This law explains why a compass needle arranges itself in a general north-and-south direction.

Why does a compass point northward? Sir William Gilbert, an English scientist, discovered why the lodestone and other compasses point northward when he found that the earth is a huge magnet with poles like those of the bar magnets which you have studied. One of these poles is located in northern Canada and the other in the continent of Antarctica.

You have observed from the experiments that a compass needle is a magnet and that its north magnetic pole points toward the north. If you will think carefully and apply the law of magnetism stated above, you will see that the earth must have a south magnetic pole in northern Canada and a north magnetic pole in Antarctica, otherwise the north magnetic pole of the compass or lodestone would point southward. Figure 386 shows this arrangement clearly and should be carefully studied to fix the idea in your thinking.

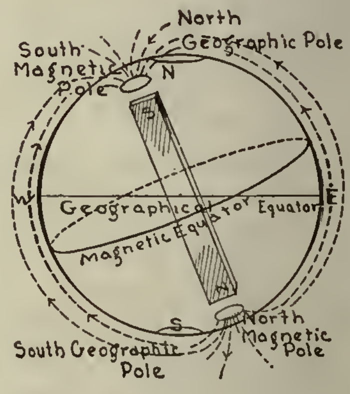


FIG. 386. THE EARTH AS A MAGNET

Since the north pole and the earth's magnetic pole in the northern hemisphere are not at the same point, the compass does not point true north but magnetic north. Allowance has to be made for this when ships are guided at sea by magnetic compasses.

On his first trip to the Arctic with airplanes, Admiral Richard Byrd found that his magnetic compasses were not reliable, and so he found it necessary to use a sun compass to locate exactly the North Pole.

Exercise. *Can you suggest a possible cause for the unreliability of the magnetic compasses in this instance?*

Figure 386 also shows the lines of force which are about the earth because of its magnetism. These lines of force are used to operate another kind of compass called the earth inductor compass, which guided Lindbergh on his historic flight to Paris.

What are electromagnets, and for what are they used? Hans Christian Oersted, a Dutch scientist, discovered in 1819 that any wire through which an electric current is flowing has a magnetic field about it. Some years later Michael Faraday, an English scientist, and Joseph Henry, an American scientist, discovered that if a wire carrying a current were wrapped

[1] *Alloy:* Some metals when melted together dissolve in one another. When such a metallic solution cools it is called an alloy.

William Thompson

FIG. 387. MICHAEL FARADAY

in a coil about a soft piece of iron, the coil and iron would act like a magnet when the current was flowing but would lose their magnetism when it was turned off. Figures 387 and 388 show Faraday and his first electromagnet.

An electromagnet has poles exactly like a bar magnet. These poles depend upon the direction in which the current is flowing about the soil. That is, if the current is made to flow through a coil in the opposite direction, the poles of the electromagnet will also be reversed.

The strength of an electromagnet can be changed either by changing the number of turns of wire or by changing the amount of current which is flowing through the coil.

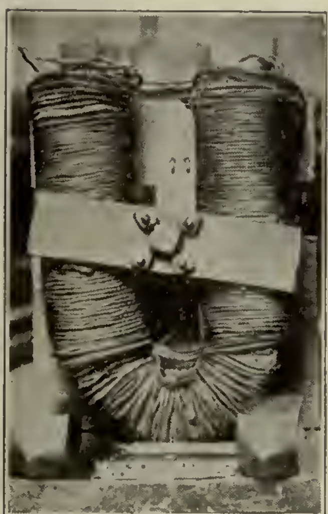


FIG. 388. FARADAY'S FIRST ELECTROMAGNET

Electromagnets have many uses. Because an electromagnet can be made to lose its magnetism by turning off the current, it is useful for loading and unloading iron around steel mills. When a large magnet like the one shown in Figure 389 is swung on a crane over a carload of scrap iron, pig iron, or railroad rails, and current is turned on, the materials can be lifted out and carried by the crane to the place where they are to be stored to await further use. The materials are released from the magnet when a switch is opened and the current is turned off.

Other uses for the electromagnet are found in the telephone receiver, the telegraph sounder, the electric bell, the electric motor, and the generator.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chaps. 21 and 22
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Skilling, *Tours through the World of Science*, Tour 10
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 17
Watkins and Bedell, *General Science for Today*, Chap. 24
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 5 (part)
Wood and Carpenter, *Our Environment: How We Use and Control It*, Topic 9

Special references

Lunt, *Everyday Electricity*
Meister, *Magnetism and Electricity*
Morgan. *The Boy Electrician*

Courtesy Ohio Electric Manufacturing Company

FIG. 389. A LARGE ELECTROMAGNET

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. What the different kinds of magnets are and how they work.
2. What a compass is and why it points north and south.
3. What a magnetic field is and how it may be mapped.
4. What magnetic lines of force are and what are their properties.
5. What an electromagnet is, its properties, and what it is used for.

TEST OF MASTERY OF TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Every magnet has ____ poles.
2. Like magnetic poles ____ and unlike poles ____.
3. The north pole of a compass needle points ____.
4. The earth is a large ____ with its north pole in the ____ hemisphere and its ____ pole in the ____ hemisphere.
5. Make a diagram of a bar magnet and draw the lines of force as they should appear about it.
6. ____ is used to map the magnetic field about a magnet.
7. The field about a magnet is made up of ____.
8. ____ and ____ were two men interested in the early development of the electromagnet.

9. Make a diagram of two bar magnets with the south pole of one facing the north pole of the other. Draw the lines of force about these opposite poles.

10. Electromagnets are used in telephone ____.

11. An electromagnet has an ____ core.

12. The strength of an electromagnet may be increased by making ____ turns of wire on the core or by ____.

13. An electromagnet ____ its magnetism when the electric circuit is broken by a switch.

14. The ____ magnetic pole of the earth is in the southern hemisphere.

15. If a person were to carry a compass needle suspended on a string to the magnetic pole in northern Canada, how would it behave?

16. In which direction would the N pole of a compass point if carried to northern Greenland?

17. Suggest a way in which the steel blade of a pocket knife might be magnetized.

18. Suggest a simple experiment by which you could identify the poles of an unmarked bar magnet.

19. A boy tried to make an electromagnet by winding a coil of insulated wire around a copper bar. What do you think the results were? Why? Suggest a way of improving his electromagnet.

20. What evidence can you give that a magnetic field really exists about a magnet? Have you ever seen the lines of force in a magnetic field?

21. Suggest a method of experiment that might prove that the magnetic lines of force about a magnet surround it completely and do not, as your experiment would seem to indicate, lie only in the plane of the table top.

TOPIC 3. HOW ELECTRICITY IS GENERATED

SUGGESTED PROBLEMS AND QUESTIONS

1. **What did Michael Faraday discover about magnetism and electricity, and how was it put to work?**
2. **What are the two types of electric currents?**
3. **How is electrical energy generated and distributed on a modern scale?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems to see if they include questions in which you are interested.

2. You may find the following new words and phrases for the first time in this topic:

commutator—a device on an electric generator to keep the current always flowing in the same direction in the outside circuit.

cutting lines of force—lines of magnetic force are cut whenever a wire or coil of wires moves across a magnetic field at right angles to the lines of force.

armature—the turning part of a motor or generator.

dynamo—a device used to change mechanical energy to electrical energy.

turbine—a machine which uses the energy of steam or water to turn it and which is used to run electric generators.

magneto—a simple electric generator using permanent magnets for the magnetic field.

induced current—a current produced in a coil whenever it breaks magnetic lines of force.

galvanometer—a device used to detect small electric currents.

field coils—coils of wire which are a part of both motors and generators. As current flows through them they supply the magnetic field needed in either device.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 153. How did Faraday secure electricity with a coil and magnet?

Wind about fifty turns of bell wire into a coil about three inches in diameter, leaving about ten inches of wire on either end. Attach the ends to a sensitive galvanometer as shown in the illustration in Figure 390. If no galvanometer is available, one may be made by winding about two hundred turns of double cotton-covered wire, No. 26, or No. 28, around a frame which can be made from a safety match box cover in the following manner. Cut the top of the cover as shown in Figure 391.

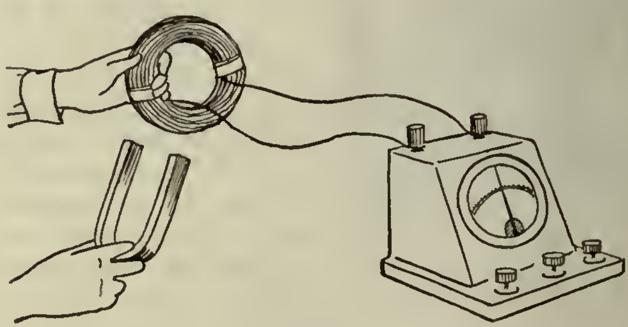


FIG. 390

Wind the coil over the bridge B in the center as shown, leaving several inches of wire on either end for connections. Place a small magnetic compass in the cover under the coil or suspend a small magnetized needle between the top and bottom of the match box cover, as shown in Figure 391.

When the coil is connected to the galvanometer, move the coil over the end of a bar or horseshoe magnet. Note any movement of the galvanometer needle and its direction. Remove the coil from the pole of the magnet and note the direction of movement of the needle. Move the magnet through the coil. Record your observations and complete the following statements in your notebook.

A movement of the galvanometer needle shows that ____ through the coils. When the coil was moved down over the magnet the galvanometer needle moved ____.

[1] See workbook, p. 89.

(Show with an arrow.) When the coil was not moving over the magnet the galvanometer needle ____. When the coil was removed from the magnet pole the galvanometer needle moved ____ (Show with an arrow). When the magnet was

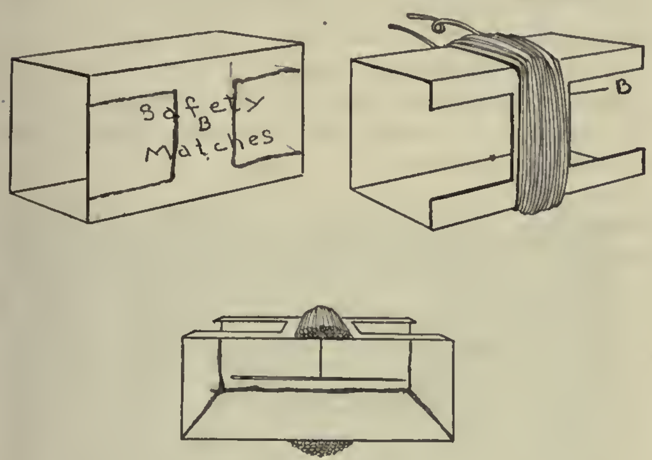


FIG. 391

moved in and out of the coil, ____ flowed in the coil and galvanometer. A current is generated in the coil whenever ____ are cut by ____.

Experiment 154. How does the magneto of a telephone or an automobile work?

Secure an old telephone magneto of the type shown in Figure 392. Study its construction carefully, noting the method of producing the magnetic field, the coil, and the provisions that are made for turning the coil rapidly in the magnetic field.

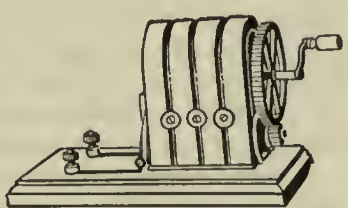


FIG. 392

Write a summary paragraph showing how Faraday's experiment is made to work in a magneto generator.

Experiment 155. How does a modern electric generator work?

A toy electric motor such as those used with Meccano and Erector sets, a St. Louis motor, or a small electric generator may be used for this experiment. Attach a table galvanometer or the one used in Experiment 153 to the binding posts of the small generator. If the St. Louis motor is used, attach the electromagnet field and place a dry cell in the circuit as shown in Figure 393. Turn the armature (the moving part of the generator) with the fingers. Notice

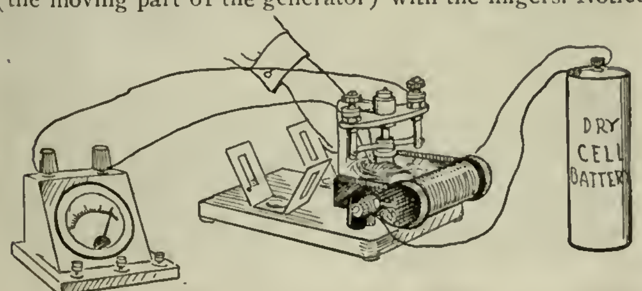


FIG. 393

the galvanometer needle. Turn the armature in the opposite direction. Record your observations. How is the magnetic field obtained? How is the current which is generated in the armature taken to the outside? Spin the armature and notice the galvanometer needle. Does it vibrate back and forth or move only in one direction? In your notebook record the notes of the experiment and complete the following statements.

The magnetic field of the generator studied is produced by an ____ magnet. The moving part of the generator is called the ____. This might be turned in the magnetic field by ____ power or ____ power. Current is generated in the ____ because ____ of wire are made to ____ across ____ of force. The current generated in the ____ is taken to an outside circuit such as the galvanometer through ____.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Visit an electric power plant and study the large generators.
2. Connect a small generator to a toy steam engine and have a model power plant.
3. Construct a model water-power plant with a small generator and a water motor.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What did Michael Faraday discover about magnetism and electricity, and how was it put to work? Michael Faraday was one of the world's greatest experimenters. Without much education but with tremendous determination and sacrifice, he followed a career in the laboratory of the Royal Institution in London because of his great love of science. He made many discoveries, but perhaps his greatest was that an electric current could be obtained by moving a coil of wire over a magnet. This came about twelve years after Oersted had made his discovery that every conductor carrying an electric current has a magnetic field about it. It is not difficult for us, living in an electrical age, to see that Faraday's discovery is one of the most important of all time. Because of his great generosity Faraday did not patent his discovery. Every light that burns, every electric heating device and motor make use of current which comes from a generator applying the principle of Faraday's experiment.

Exercise. *After carefully reading the foregoing paragraph about Michael Faraday, make a list of the traits which he had that in your judgment made him a great scientist.*

Electricity is generated in a conductor that cuts across magnetic lines of force. It makes no difference whether the coil or the magnet be moved, just as long as the lines of force are broken. The amount of electrical energy obtained in this way depends upon three things—the number of lines of force, the number of conductors or coils of wire, and the speed with which the lines of force are cut. The direction in which the electric current flows in the coil depends upon the direction in which the lines of force are cut. For ex-

ample, if the coil in Figure 394 is moved downward over the magnet, the lines of force are cut in the order as numbered, 1-2-3-4-5-6, and the throw of the galvanometer needle is to the right. Now if the coil is taken from the magnet as shown in the figure, the lines of force are cut in the reverse order of 6-5-4-3-2-1, and the galvanometer needle throws to the left, showing that the current is now flowing around the circuit in the opposite direction. If the coil is moved very rapidly up and down over the magnet, the needle will vibrate back and forth, showing that current is flowing first in one direction around the circuit and then in the other. This is called an *alternating current*. Modern generators produce current which alternates sixty times per second. This is so rapid that we do not notice it in lights or heating devices.

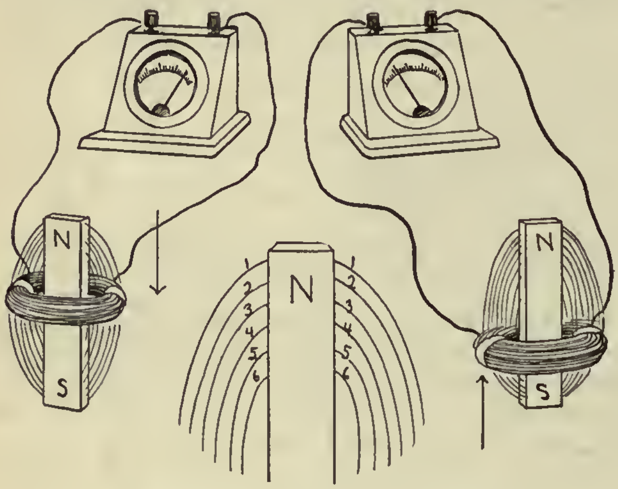


FIG. 394. HOW ELECTRICITY IS GENERATED

The discovery made by Faraday remained a laboratory experiment for more than forty years until the genius of Thomas A. Edison saw the possibilities of producing electricity on a large scale by making an electric generator which used coils and magnets.

The simplest form of electric generator is the magneto; it is used in rural telephone systems and in certain automobiles for generating the current used to charge the storage battery. In the magneto the magnetic field is supplied by permanent magnets. The armature is made of many turns of wire and revolves rapidly in the magnetic field where the lines of force are cut many times per second. In the modern electric generator the permanent magnets in the field of the magneto are replaced by electromagnets. In small generators current is taken directly from the armature and run through the field electromagnets. In the larger ones it is necessary to have a separate generator, called an "exciter," to furnish current for the field magnets.

What are the two types of electric currents. When you repeated Faraday's experiment you observed that if the lines of force were cut in one order the current flowed in one direction around the circuit while if they were cut in reverse order the current flowed in the opposite direction. The coils of wire in the armature of an electric generator cut the lines of force in the magnetic field in one order during a half revolution and in the reverse order in the next half revolution. This is shown in Figure 395, where a single coil in a magnetic field is illustrated. If the coil is rotated in the magnetic field in the direction indicated by the arrow, while the section of the coil AB is cutting the lines of force in the order 1-2-3-4-5 as numbered, the section CD is cutting them in the order 5-4-3-2-1. In the next half revolution the conditions are reversed and the current in each section of the coil reverses. If each end of the coil were attached to two rings which turn with the coil, the current thus generated could be taken to outside lights, electric irons, and other household devices by means of brushes which rub on rings. In this way the current in the outside circuit of lights would change its direction each time the current in the armature reversed, once each half revolution. This type of current is called alternating.

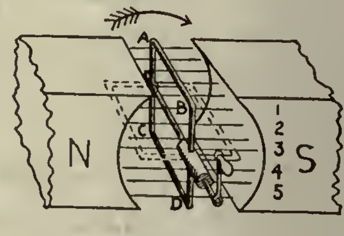


FIG. 395. GENERATION OF ALTERNATING CURRENT

It is sometimes necessary to make the alternating current generated in the armature one which always flows in the same direction outside the generator. To do this a slight change is made in the device on which the brushes rub. Instead of two continuous rings as in the A.C. generator, the ends of the coil are now connected to a *split ring* or *commutator* as shown in Figure 396. In this generator, just as the current reverses in the armature coil, the commutator segment attached to it slips over to the other brush. This means that brush B will always be in contact with the coils which are cutting the lines of force in one direction and brush C in contact with those coils cutting lines of force in the opposite direction. Thus current will always flow in one direction, out of one brush, around the outside cir-

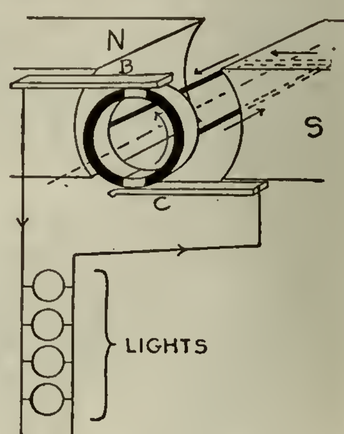
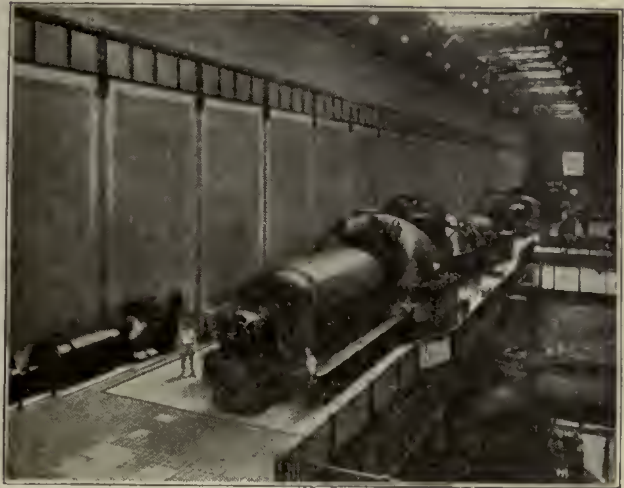


FIG. 396. USE OF THE COMMUTATOR

cuit, and in at the other brush. Large direct current generators have many more divisions in their commutators.

How is electrical energy generated and distributed on a modern scale? Electrical generators are sometimes run by steam engines. The earliest forms of commercial generators had the coils of their armatures turned in the magnetic field by steam engines.

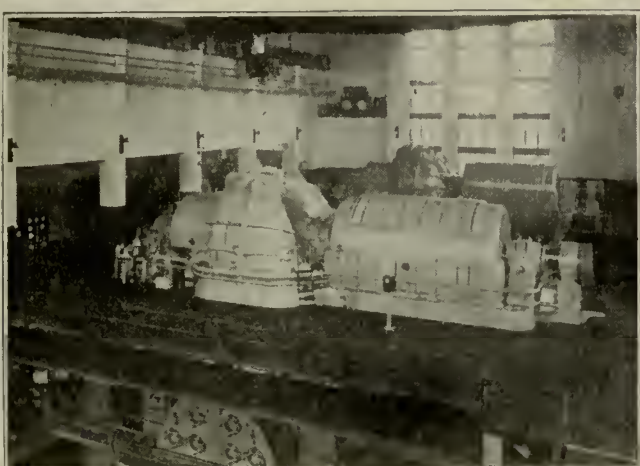
While steam engines are still used to a considerable extent, the most modern method for using steam for generating electricity is with the steam turbine. Steam at high pressure is allowed to expand and push against revolving blades. This gives a very rapid whirling motion to the shaft to which they are attached. The armature of the electric generator is attached to the same shaft and is turned by the rapidly turning vane wheels of the turbine. Figure 398 shows a modern steam turbine attached to a generator.



Courtesy Union Electric Light and Power Co.

FIG. 397. A MODERN ELECTRICAL GENERATING PLANT

Exercise. *Trace the energy of the electricity secured from a generator by means of a steam engine or turbine, through all of its transformations, to its remotest source.*



Courtesy General Electric Company

FIG. 398. MODERN ELECTRIC GENERATOR AND STEAM TURBINE

Falling water has tremendous energy. Man has long utilized this energy to turn the wheels of mills and factories which were built along the streams. The use of falling water to generate electricity makes it possible to have the factories many miles away, for electrical energy can be sent long distances through wires.

At Niagara Falls there is a great industrial center which makes use of the falling water for power. Great dams have been built in many other places to raise the water to high levels so that as it falls its energy may be used to turn the armatures of great electrical generators.

To get the energy of the falling water into turning motion, a water turbine is used. In many ways it is like the steam turbine shown in Figure 398 except that water instead of steam is used to drive it. The turbine is then attached to the armature of a generator which turns in a magnetic field.

Exercise. *Trace the electrical energy secured from a generator by means of a water turbine, through all of its transformations, to its remotest source.*

Transformers are used when electricity is sent long distances. Alternating current is used when electrical energy is to be sent far away from the power plant to be used. Electricity is just like water in that if it is to be sent for some distance it must have great pressure at the sending end to overcome the resistance of the conductor which is carrying it. The pressure of alternating current can be raised or lowered much more easily and more cheaply than that of direct current.

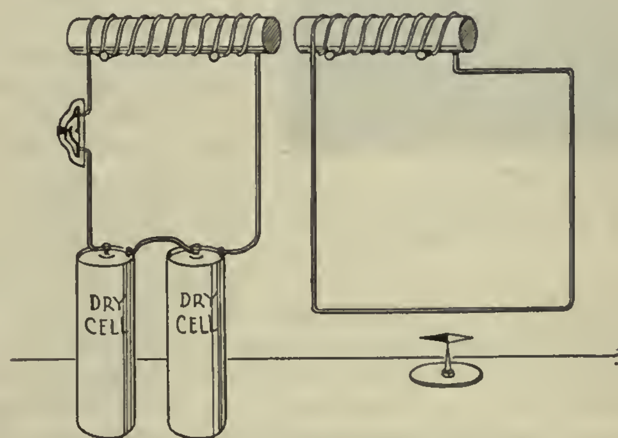
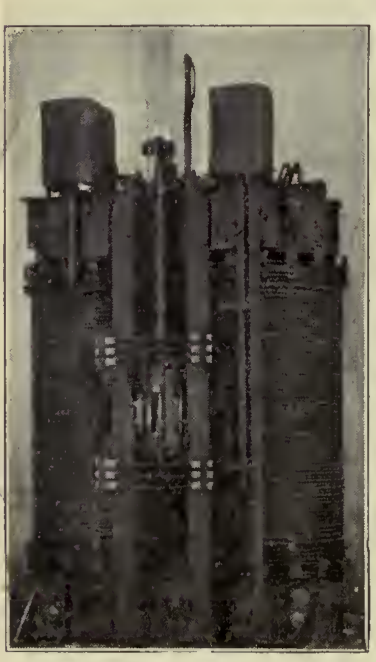


FIG. 399. PRINCIPLE OF THE TRANSFORMER

To raise or lower the electrical pressure or voltage of alternating current a device called a *transformer* is used. The type that lowers the voltage is commonly used to operate toy electric trains and furnish current for door bells. Transformers used to raise the voltage

are known as the *step-up* type and those used to lower the voltage *step-down.*

The working of a transformer is easily understood if one keeps in mind some of the things already learned about magnetism and electricity. You will recall that every electric current has a magnetic field about it and that if magnetic lines of force cut across conductors a current will be set up in the conductor. The amount of the current depends partly upon the number of conductors cut by the lines of force. You must learn one new fact about magnetic fields to understand fully the operation of the transformer. The magnetic field about a direct current is steady while the one about an alternating current is continually moving. As the current flows in one direction the magnetic field builds out around the conductors, and then as the current reverses it stops for a moment and builds up again as the current flows in the opposite direction. This keeps the magnetic lines of force always moving.



Courtesy General Electric

FIG. 400. LARGE TRANSFORMER WITH SHELL REMOVED

In the transformer two coils are wound on an iron core as shown in Figure 399. The one which leads from the generator is called the *primary* winding and the other the *secondary* winding. In each type of transformer there are more turns of wire in the high voltage winding than in the low voltage winding. As the current flows in the primary winding its magnetic lines of force surge through the iron core and cut the coils in the secondary and either raise or lower the electrical pressure, depending upon the number of turns of wire in it.

Exercise. *Carefully study the diagram shown in Figure 399. Which is the primary coil? Which is the secondary coil? Predict the effects when the push button is closed. Is this a step-up or a step-down transformer? Give evidence to support your statements.*

One of the most difficult problems which the power companies have had to solve is transmitting the electrical energy from the generating station to the home or industry where it is consumed. Generating stations are, as a rule, placed as near the source of natural energy as possible. This is particularly true in water-power plants and is usually the case where coal is the source of the energy. In the latter case, transporting the fuel great distances is costly, and transporting the electricity over wires is simpler.

When the place of consumption of the electrical energy is a considerable distance from the generating plant, step-up transformers, which raise the voltage of the electricity usually to about 66,000 volts, are used. It is not unusual to use much higher voltages in transmitting electricity over such lines, which are known as high tension or power lines. Where the high tension lines are to be tapped for using the electricity, they are led to a substation which contains step-down transformers to reduce the voltage to the required point.

There is less loss of energy in the transmission line when the voltage is high because as the voltage is raised the current in amperes is reduced in proportion. Since line losses are due mostly to the heat energy that results from the resistance of the wires, and since resistance is less when the current is less, it is much more economical to transmit the electricity at high voltage and low amperage.

Ordinarily the substations that receive the high voltage currents from the generating station reduce the line voltage from 66,000 volts, or higher, to about 2,200 volts. From these substations the current is carried about the city or town at the reduced voltage.

Twenty-two hundred volts is still an extremely high and dangerous voltage to handle. In fact, such a voltage is almost always fatal to one who touches a wire carrying it. It is obvious, then, that this high voltage could not possibly be brought into our homes for general use. The appliances in our homes are designed to operate at one hundred ten volts; it is therefore necessary further to reduce the voltage from the twenty-two-hundred line voltage to the house voltage of one hundred ten. This is accomplished by what is known as a "line" or distribution transformer. These transformers may be seen as iron casings usually placed on poles in various parts of a city or town. In these transformers the voltage is stepped down from 2,200 to 110 and then delivered to the homes.

REFERENCES FOR FURTHER STUDY

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Hunter and Whitman, *Science in Our World of Progress*, Unit 7; *Science in Our Social Life*, Unit 7

Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 23

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Powers, Neuner, and Bruner, *Man's Control of His Environment,* Unit 5
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Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 17
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Webb and Beauchamp, *Science by Observation and Experiment,* Unit 5 (part)
Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 9

Special references

Lunt, *Everyday Electricity*
Meister, *Magnetism and Electricity*
Darrow, *Masters of Science and Invention*
Morgan, *The Boy Electrician*
Collins, *The Book of Electricity*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Understand thoroughly the principle of securing electrical energy from mechanical energy.
2. Know the contributions of Faraday and Edison to the development of the modern electric generator.
3. Have a knowledge of how modern electrical plants secure the mechanical energy needed to turn the dynamos.
4. Understand the importance of conserving our present sources of energy such as coal, oil, and water power.
5. Know the two types of electric current and what they are used for.
6. Understand the principle of the transformer.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements.

1. The ____ is the moving part of an electric generator.
2. An electric current is produced whenever a ____ moves in a ____.
3. In the magneto-generator the magnetic field is furnished by ____ magnets.
4. If the armature of a generator is turned ____, more ____ is produced.
5. Generators equipped with commutators give (alternating, direct) ____ current.
6. ____ current is produced in the ____ of all electric generators.
7. All batteries give (alternating, direct) ____ current.
8. Magneto generators are sometimes used to ____.
9. ____ discovered the principle of the electric generator.
10. ____ built the first electric generator.
11. The amount of electrical energy produced by a generator depends upon the number of ____, the rate of ____, and the number of ____.
12. Steam or ____ may be used to turn the ____ of a generator in the ____ field.
13. A direct current always flows ____.
14. The ____ of a dynamo take the current from the commutator.
15. The telephone magneto furnishes ____ current to the outside circuit.
16. Any generator applies the discovery made by ____.
17. Transformers are used to ____ or ____ electrical ____.
18. Transformers are used only with ____ current.
19. If the ____ is raised by a transformer there are more turns in the ____ coil than in the ____ coil.
20. When the voltage is raised in a transformer the ____ is lowered. This ____ line losses because they are caused mostly from ____ of the wires, and this depends upon the number of ____ flowing through them.
21. Electricity from the generating station is reduced in ____ at a point in the transmitting system called a ____.
22. Most electrical devices used in the home are designed to operate at ____ volts.

TOPIC 4. USING ELECTRICITY ABOUT THE HOME

SUGGESTED PROBLEMS AND QUESTIONS

1. **What are electric fuses for, and how are they replaced?**
2. **How do electric heating devices work?**
3. **How do electric lights work?**
4. **How do electric motors work?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems to see if you are interested in them.

2. Get as much experience in replacing fuses and in observing electrical heating devices, motors, and lights as you can. This can be done both at home and at school.

3. In this study the following new words and phrases may be encountered:

insulator—a substance which will not conduct the electric current.

resistance—a retarding experienced by the electric current as it flows through various conductors; from this resistance heat energy is developed.

nichrome—an alloy of nickel, chromium, and iron which has a high resistance for the electric current. This is often used in the heating element of toasters, electric irons, etc.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 156. What happens when a fuse burns out?

Make a fuse board as shown in Figure 401, driving the nails about one inch apart. Cut a strip of tin foil wrapper secured from a candy bar and attach it to the nails. Connect the wires to the nails as illustrated and finally to the battery through a push button or switch. Allow current from the dry cell to flow and observe what happens. Hold a small piece of the tin foil in a match flame. Examine new and burned-out fuses. Secure a piece of fuse wire from an un-

[1] See workbook, p. 91.

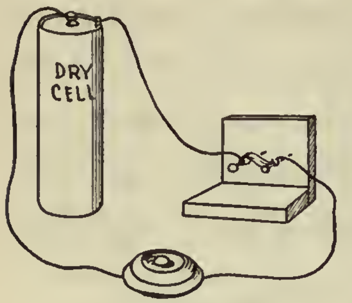


FIG. 401

used fuse and hold it in a match flame. Record your observations and complete the following statements in your notebook.

The fuse used in this experiment had a ____ melting point as demonstrated by holding it in a ____. When electric current flows through it, a wire becomes ____ because of the ____ which it offers to the current. When a large current flowed in the circuit sufficient heat was developed to ____ fuse. This ____ the circuit and no more current could flow until ____. Ordinary fuse wire, as shown by this experiment, has a ____ melting point.

Experiment 157. How do electric heating devices work?

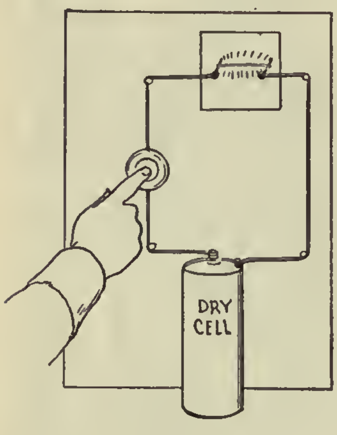


FIG. 402

Set up a board as shown in Figure 402. Tack a piece of asbestos about four inches square to the board and drive two small nails three inches apart through it into the wood. Lead a wire from a dry cell through a switch or push button to one nail and another from the battery to the other nail. Secure a piece of fine iron wire about four inches long and attach the ends to the nails. One strand of picture wire will work well for this. Allow current to flow for a very short time by closing the circuit at the push button or switch. Remove the iron wire and replace it with a copper wire of about the same size. Again allow current to flow. Observe an electric toaster or other electrical device with an open heating element. Study its construction and observe the heating element when it is cold. If possible, secure a piece of the heating element from an old toaster or flatiron and connect it between the nails in your set-up. Record your observations and complete the following statements in your notebook.

When current from the battery flowed in the circuit, the iron wire ____ while the copper wire ____. This was due to the fact that ____ offers more resistance to the current than ____. ____ would be better than ____ for use in an electric heating element, as shown by this experiment.

Activity 158. How do electric lamps work?

Secure an unfrosted electric-light bulb and study it carefully. Trace the current from the point where it enters the bulb to the point where it leaves. Study the method used to remove the air from the bulb. Study the filament and learn how a high resistance is secured. Learn how the filament is supported. Is the filament made of the same material as the wire which goes through the glass stem at the base? Examine the way in which the glass bulb is fastened to the brass shell.

In your notebook, diagram the bulb which you studied, showing the pathway of the current through the bulb. Letter the diagram to identify the filament, the brass shell, the air removal tube, and the contact buttons. Complete the following statements.

The filament is made of ____. The material marked ____ is an insulator between the upper contact button and the ____. The brass shell is fastened to the globe with ____.

Experiment 159. How does the electric motor work?

Suspend a bar magnet and bring another one near it so that two unlike poles are together. Keep turning the poles of the magnet in the hand in such a way that the suspended magnet rotates. Connect a dry-cell battery to a small Erector motor or a St. Louis motor having permanent bar magnets for the field.

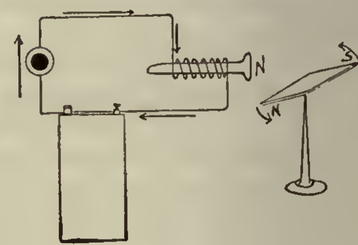


FIG. 403

In your notebook complete the following statements.

The rotating part of this motor is different from the rotating magnet in the part above in that this is an ____ magnet while the one above is a ____ magnet. The armature of this motor (has, does not have) ____ a commutator. (Direct, Alternating) ____ electric current is furnished by the dry cell. From Experiment 152 you learned that the poles of an electromagnet can be reversed by reversing the ____ flowing in the coil. The commutator of the motor does this each half revolution.

How the armature poles of a motor change—Set up an electromagnet as in Figure 403. Bring a compass near the electromagnet. Press the push button and determine the polarity of the head of the nail. Reverse the current through the electromagnet by reversing the battery connections. Again test the polarity of the head of the nail. The nail and coil represent one coil in the armature. The commutator of the motor reverses the current through these coils each half revolution, thus reversing their polarity.

In your notebook complete the following statements.

Unlike poles of two magnets ____ and like poles repel. The polarity of electromagnets may be reversed by ____ the current flowing in them. The armature of a motor is an ____ magnet. The current in the armature is ____ each half revolution by the ____. This ____ the poles of the armature each ____ revolution, causing attraction and repulsion between the poles of the ____ magnets and armature ____ and resulting in the rotation of the ____.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Learn how to replace the fuses in your home.
2. Learn how an arc lamp works.
3. Wire a miniature house system on a board with fuses, lights, heating devices, etc.

READING WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What are electric fuses for, and how are they replaced? In the same way that water flows through a smooth pipe more easily than through a rough one, electricity flows more easily through some things than

others. Substances that let the electricity flow easily through them are said to have less resistance than those through which it is harder to flow.

Whenever electricity flows through a wire it produces some heat, but much more in substances that have high resistance than in those that have low resistance. This was clearly shown in your experiment; the iron becomes hot because it has more resistance than the copper.

Fuses are safety valves for electric currents. When electricity became a common thing around the home for lighting, heating, and running cleaners, people found that oftentimes bare wires in the electric iron or lamp got crossed and allowed large amounts of current suddenly to flow through them. A *short circuit* was created, and if the wires were not separated at once so much heat developed that the covering on the wires took fire and burned. This, of course, was dangerous, as the wires were frequently placed between the walls.

The electrical fuse was developed to make a safety valve which would prevent fires. The fuse is a piece of soft metal something like solder which melts at a very low temperature. When a short circuit occurs, the heat developed melts the fuse wire and breaks the electrical pathway before the covering on the wire has had a chance to take fire.

Fuses are of two common types, plug or screw fuses and cartridge fuses. For home use the plug or screw type is more common, while the cartridge type is used more for industrial purposes where large amounts of current are used. In Figure 404 the construction of the plug type of fuse is shown. The strip of fuse metal *F* is enclosed in a porcelain plug with a small mica window at *W*; the window enables one to tell when the fuse has been burned out and also keeps it enclosed to prevent sparks, which fly when the fuse wire melts, from setting anything on fire..

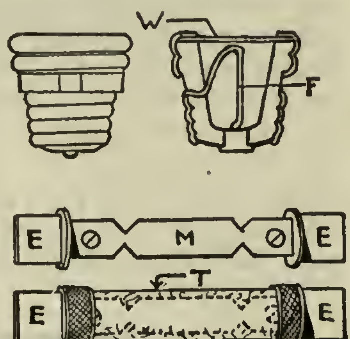


FIG. 404. TWO TYPES OF FUSE

Figure 404 also shows the construction of the cartridge type of fuse. The strip of fuse metal *M* is attached through an insulating tube *T* to the metal ends *E*. The tube *T* around the fuse metal is packed with asbestos or some other substance which will immediately quench any spark which forms when the fuse metal melts.

The diagram, Figure 405, shows where fuses are usually placed in a house wiring plan. When fuses burn out it is a simple matter to replace them. First throw off the main switch which will be found near the fuse box and determine which fuse has been burned by examining the little mica windows of both the circuit fuses and the main fuses. The window of a burned fuse is usually clouded. Remove this fuse and screw in a new one, throw on the main switch, and test by lighting the lights in various parts of the house. Keep extra fuses on hand for emergencies.

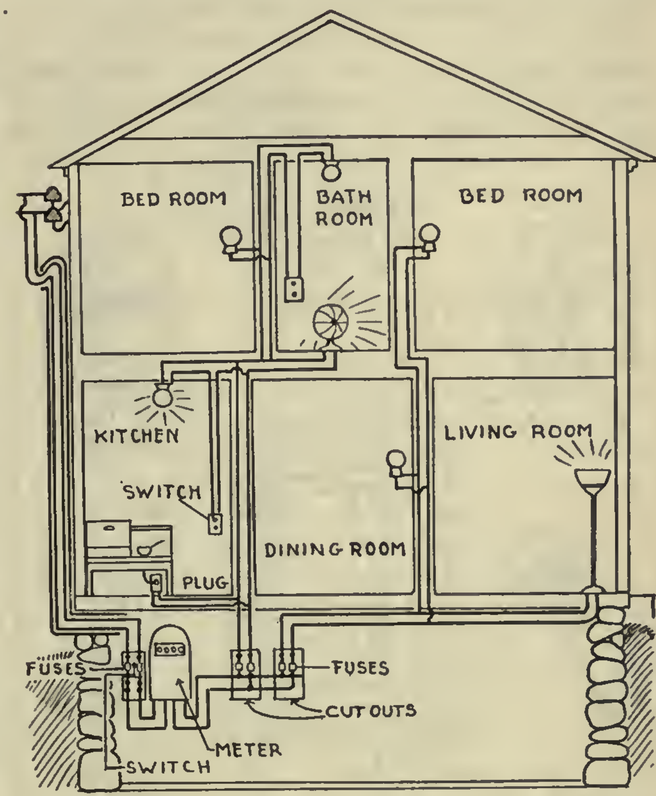


FIG. 405. HOUSE WIRING PLAN

Never use a makeshift fuse or temporary replacement, as it may cause a fire.

Exercise. *Often, when a fuse burns out in the home, a penny or other metal object is placed behind the burned-out fuse to make the connection previously made by the fuse metal. Suggest the dangers involved in such a practice.*

How do electrical heating devices work? Much of the increase in the use of electrical energy during the past few years has been due to the fact that it may be easily transformed into heat energy with very little loss, and heat energy thus obtained is free of smoke and gases, while coal, oil, and other common fuels are not. Another important fact in the rapid increase in the use of electrical energy for heat is that it may be controlled much more accurately than heat from other sources.

In the home, heat from electrical energy is used in ranges for cooking and baking, in toasters, electric irons, hot plates, hot pads, heaters, and other

devices. In industry, electric heat is used in bakeries, in laundries, and in the manufacture of many common substances such as carborundum and steel. The ovens in which the large block of special glass for the 200-inch reflecting telescope was made were heated by electricity. It was necessary to allow the cooling of this glass block to go on very slowly and evenly. Electric heat was the only heat in which the precise control of the temperature could be obtained.

Devices which transform electrical energy into heat energy usually have heating elements made from some material which offers so much resistance to the flow of the electric current that it will become red

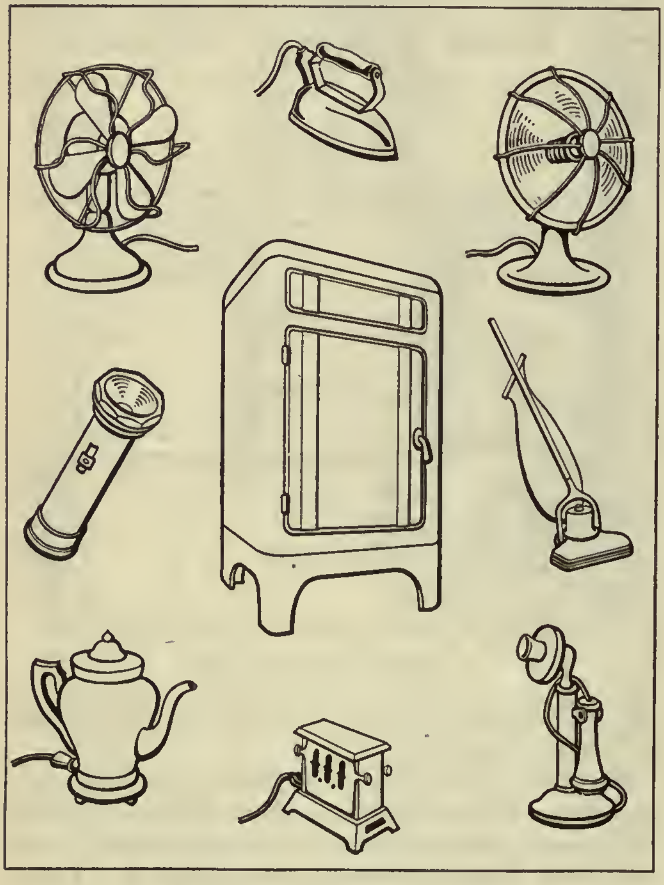


FIG. 406. DEVICES WHICH CONVERT ELECTRICAL ENERGY INTO OTHER FORMS OF ENERGY

hot. Many patented alloys for these heating elements are in use. They vary in their chemical composition, but usually contain nickel, chromium, and iron. Examine the heating element of an electric heater or toaster and note the color and general characteristics of the material from which it is made.

How do electric lights work? In flashlights, automobiles, and homes and for street lighting, electric lamps of every description are used.

The earliest experiments in changing electrical energy into light energy were made by Sir Humphry Davy, a great English scientist. He discovered that when current from his large battery was brought through two pieces of carbon, which were afterwards slightly separated, a brilliant light was produced. Later this discovery was developed into the modern arc lamp. When the carbons in Figure 407 are touched and then slightly separated, current continues to flow across the air gap between them, giving a very bright light and a great amount of heat. This type of light was very common a few years ago for street lighting and now is used widely in one type of health or "sun-ray" lamp.

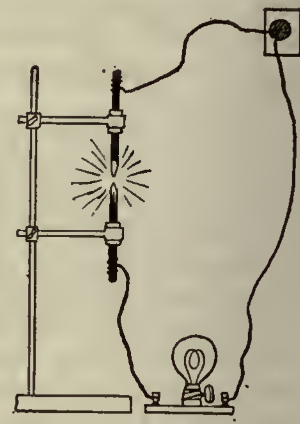


FIG. 407. SIMPLE ARC LAMP

After the development of the electric generator, Thomas A. Edison turned his attention to the problem of producing a device which could change electricity into light. After long and careful experimenting, often with most discouraging results, he produced in 1879 the first electric lamp. In the development of this lamp many perplexing problems had to be solved, such as finding a substance which would last for some time as a filament, getting the electricity into the globe, and removing air from it.

Carbonized cotton was finally found to be a suitable material for the filament, and after the air from the bulb was removed to prevent the filament from burning, a lamp was successfully operated for a period of forty hours.

In the fifty years which have passed since this historic experiment, great progress has been made in electric lighting. Tungsten, a metal with a very high melting point, has replaced carbon as the filament. Gases which will not combine with the hot filament are put into the globe after most of the air has been removed. Globes are now frosted on the inside to prevent glare. Truly great advances have been made, but what a debt we owe to the great mind that first made these developments possible.

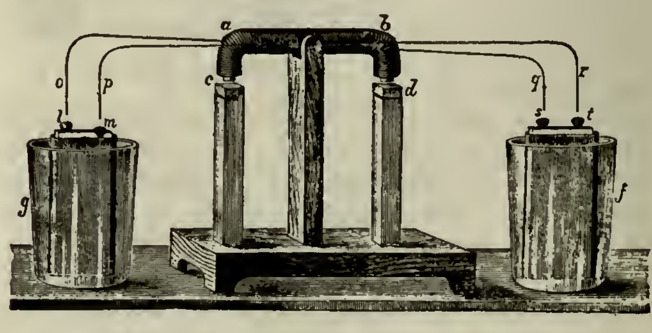
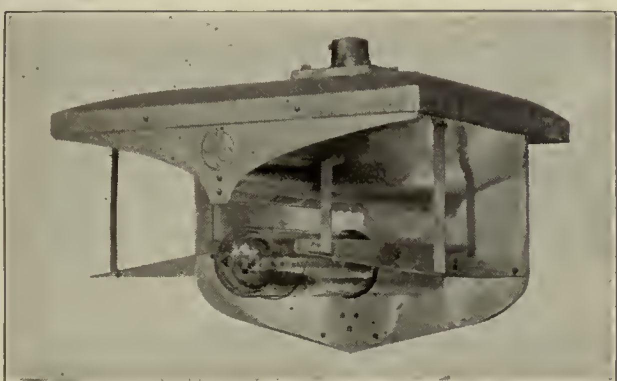


FIG. 408. HENRY'S DIAGRAM OF A MOTOR

In the past few years a new type of lamp has been developed which is known as the sodium vapor lamp. Its greatest importance lies in the fact that it is very efficient. In this type of lamp one unit of electricity will produce a light intensity equal to that which requires two and one-half units in an ordinary lamp.

The sodium vapor lamp finds its greatest use in outdoor illumination for highways, tennis courts, and buildings. It is not probable that it will be used to any great degree for indoor illumination because it gives a brilliant yellow light that does not contain the other colors of the spectrum. Things with color and persons take on peculiar appearances under the sodium vapor lamp.

How do electric motors work? Electric motors change electrical energy to mechanical energy. Much of the use of electricity about our homes is made possible because electricity can be made to produce motion. Electric vacuum cleaners, washing machines, ironers, sewing machines, and other devices depend for their operation upon electric motors. Outside the home we find motors used to drive street cars and to turn the wheels of a great many industries. The electric motor has made the work of mankind much easier.



Courtesy General Electric Company

FIG. 409. SODIUM VAPOR LAMP

The motor accomplishes a change of energy exactly opposite to that which occurs in the generator, in which energy of motion was changed to electricity. In the motor the energy of electricity is changed to motion. The generator and motor are not greatly different, as many generators can be run as motors if they are supplied with electrical energy, and many motors can be used as generators if their armatures are turned.

Joseph Henry discovered a way to produce motion from electricity about one hundred years ago. Though his simple toy was only a rocker, he saw the possibilities of the modern motor. The illustration, Figure 408, is taken from Henry's notes, and in his drawings *g* and *f* are two batteries, each connected to wires leading to the armature *b*, which is an electromagnet. The batteries are so connected that when the ends *op* are connected with the battery *g*, current will flow in one direction through the armature, and when the ends *qr* are connected with battery *f*, current will flow in the opposite direction, thus reversing the polarity of the electromagnet each vibration. Placed under the poles of the electromagnet are permanent magnets *c* and *d*. These alternately attract and repel the poles of the armature, thus giving to it a seesaw motion.

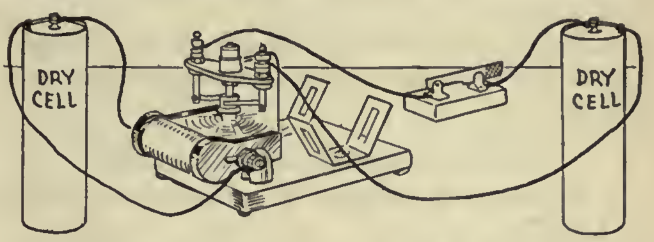


FIG. 410. SMALL DIRECT-CURRENT MOTOR WITH DRY CELLS

The modern electric motor is similar in construction to the generator, having field coils of electromagnets, an armature, brushes, and a commutator if it is used on direct current. The picture, Figure 410, shows the field coils, armature, commutator, and brushes of a small direct current motor.

As current from the dry cell flows through the armature and field coils, they become electromagnets with separate magnetic fields. The current direction in the armature is reversed by the commutator each half revolution, thus reversing its polarity. The push and pull between the like and unlike poles of these electromagnets causes the armature to turn.

Exercise. *Trace to its remotest source the mechanical energy secured from an electric motor.*

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 23
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 15 and 16 (part)
Hunter and Whitman, *Science in Our Social Life,* Unit 7
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 24
Pieper, and Beauchamp, *Everyday Problems in Science,* Unit 14
Powers, Neuner, and Bruner, *Man's Control of His Environment,* Unit 5
Skilling, *Tours through the World of Science,* Tour 10
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 17
Watkins and Bedell, *General Science for Today,* Chap. 25
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 5 (part)
Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 9

Special references

Collins, *The Book of Electricity*
Darrow, *Masters of Science and Invention*
Lunt, *Everyday Electricity*

Meister, *Magnetism and Electricity*
Morgan, *The Boy Electrician*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. How fuses are constructed, how they burn out, and how to replace them.
2. How electric devices are constructed and how they work.
3. How electric-light bulbs are constructed and how they work.
4. Something about the invention of the electric light.
5. How electric motors are constructed and how they work.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements and answer the questions.

1. Fuses are made of substances with ____ melting points.
2. Fuses are rated in ____.
3. When replacing fuses one should first ____.
4. In Figure 411 the ____ type of fuse is shown at *A* and the ____ type at *B*.

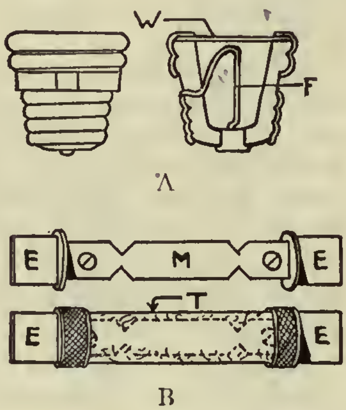


FIG. 411

5. The heating effect of electric currents is due to the ____ of the ____.
6. Fuses have ____ to prevent danger from fire when they burn out.
7. The element of electric heating devices is usually made of ____.
8. The part of the electric bulb shown at *A* in Figure 412 is called the ____ and is made of ____.
9. The terminals are shown at ____ and ____.
10. *C* is made of ____.
11. ____ has been removed from the space shown at *E* to prevent ____.
12. ____ gas is sometimes used in the space shown at *E*.
13. The parts marked *G* ____ the filament.
14. *F* is a ____.

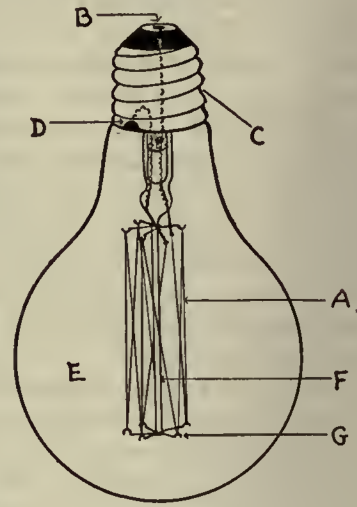


FIG. 412

15. The moving part of an electric motor is called the ____.
16. The ____ field for the motor is supplied by ____ magnets.
17. The electric motor changes ____ energy into ____ energy.
18. Motors which have a commutator use ____ current.
19. The push or pull between two ____ fields causes the ____ of the motor to rotate.
20. What are the principal advantages around the home in the use of heat secured from electricity? What are the disadvantages?
21. A new type of light recently developed for lighting ____ and ____ is known as the ____ vapor lamp. Its chief disadvantage for indoor illumination is ____.
22. Another device used to transform electrical energy to light energy is known as the ____ lamp. In it current is carried across a gap between two ____ electrodes by ____ vapor. The light of this lamp is supplied by the heating to ____ of tiny particles of ____ drawn out of the electrodes.

TOPIC 5. HOW ELECTRICITY IS MEASURED

SUGGESTED PROBLEMS AND QUESTIONS

1. **How are electric currents measured?**
2. **What important law governs electric currents?**
3. **How is the cost of electricity determined?**

SUGGESTIONS AND HELPS FOR STUDY

1. Carefully study the problems to see if they include questions which you have wondered about or are interested in.

2. In this exercise you will learn a very important law of electricity known as Ohm's Law. It was discovered by George S. Ohm, a German scientist, who lived about a century ago. You should be sure to understand this law.

3. You will learn how to calculate the cost of electricity used in the home. Learn to read an electric meter if you have not already done so.

4. You may encounter the following new words and phrases in this study. Use them as frequently as you can in order that they may become a part of your vocabulary.

ampere—the unit of current flow in electricity.

volt—the unit of electrical pressure.

ohm—the unit of electrical resistance.

watt—a unit for measuring the rate at which work is done by an electric current.

kilowatt—one thousand watts.

kilowatt hour—the amount of work done in one hour when an electric current is working at the rate of one kilowatt.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 160. How can the current flow and the electrical pressure of a dry cell be measured?

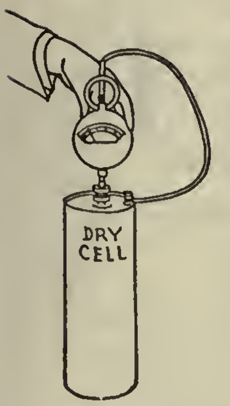


FIG. 413

A common battery tester like the one shown in Figure 413 is usually constructed in such a way that both the current flow in amperes and the pressure in volts can be measured with it. Secure such a tester and three dry cells. Measure the current flow of each cell. Measure the electrical pressure of each cell. Now connect the three cells together in series, that is, the positive pole of one to the negative of the next, and so on. Repeat the measurements. Next, connect the three cells in parallel, that is, all the positive poles together and all the negative poles together. Again measure the current and the pressure. In your notebook tabulate results of the measurement and complete the following statements.

Current flow is measured in ____ and electrical pressure in ____. A single dry cell will give ____ of pressure.

Make diagrams of three cells in series and three cells in parallel. Complete the following statement. Three cells in series gave ____ volts, while in parallel they gave ____ volts.

Activity 161. How are electric meters read?

Locate the electric meter in your home and make a careful copy of the dials and the position of the hand on each. Examine the dial face shown in Figure 414. Notice that the first dial on the right is numbered in such a way that the hand turns to the right, the second dial hand turns to the left, the third to the right, and the last one to the left.

The right dial, marked 10, records ten kilowatt hours when the hand has gone around once, each division on the dial being one kilowatt hour. The next dial, marked 100, records one hundred kilowatt hours, and when the hand of

FIG. 414

the 10 dial has made one complete revolution, or 10 kilowatt hours, the 100 dial hand will have moved down to 1. When the 10 dial hand has made ten turns, the 100 dial hand will have gone around just once, and the next or 1000 dial hand will have moved down to 1. When the 1000 dial hand has moved once around the dial, the 10,000 dial hand will point to 1.

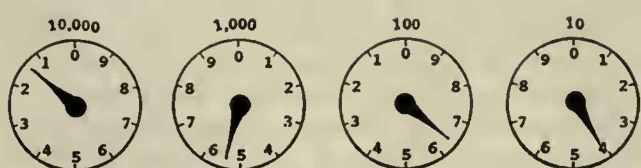


FIG. 415

[1] See workbook, p. 94.

In reading the meter, read the 10 circle first, the 100 next, the 1000 next, and last the 10,000. Study the dials in Figure 415. Notice that the 10 dial hand points to 4. The 100 dial points between 6 and 7. Read the last number which the hand passed, or 6. Read the 1000 dial 5, as the hand


FIG. 416

points between 5 and 6 and the 5 was the last number passed. The 10,000 dial reads 1. The complete reading then is 1,564 kilowatt hours. Always read the 10 dial first and the others in order, reading the last number passed by the hand.


FIG. 417

Read the dials in Figures 416 and 417 and record them in your notebook. Also read the meter reading at your home.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Make a reading of your electric meter in two successive weeks and determine the amount of electrical energy used.
2. Learn to read a gas meter and a water meter.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How are electric currents measured? Everyone knows that water currents flow through pipes. Electric currents are similar except that wires instead of hollow pipes are used. Electricity will not flow unless it has a complete pathway as shown in Figure 418. The electric current would not flow from the battery through the switch and through the bell unless the points *A* and *B* were connected by a wire or other conductor.

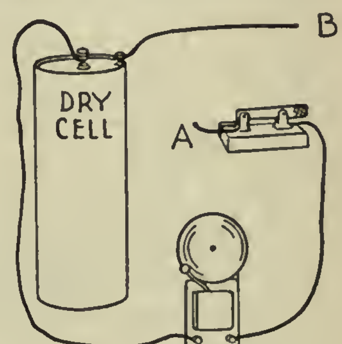
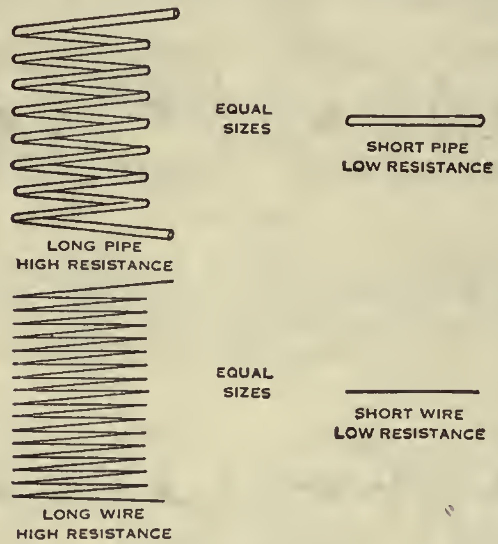


FIG. 418

Pressure furnished by force pumps makes water current flow through pipes, while pressure furnished by batteries or generators forces electric currents through the wires of a circuit. Rough pipes tend to hold back the flow of water through them, and conductors also offer resistance to the flow of electric currents. As shown in Figure 419 and Figure 420 a

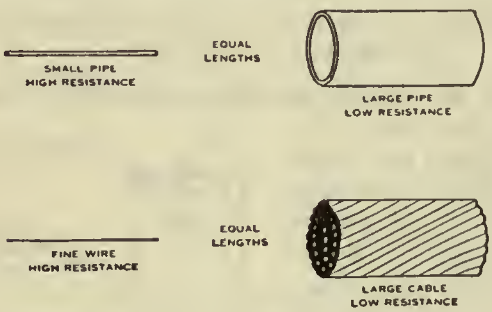
long wire offers more resistance than a short one of the same size just as a long water pipe offers more resistance to a water current than a short one.



Courtesy National Carbon Company

FIG. 419. COMPARISON OF WATER CURRENTS IN PIPES AND ELECTRIC CURRENTS IN WIRES

Turning on an electric light, iron, or motor by snapping a switch is similar to turning on a faucet in a water system. It makes possible the flow of electric current in one case and of water current in the other.



Courtesy National Carbon Company

FIG. 420. SMALL PIPES AND WIRES HAVE HIGH RESISTANCE; LARGE PIPES AND WIRES HAVE LOW RESISTANCE

If one wishes to measure the rate at which a water current is flowing from a faucet, he can use a gallon measure and watch and easily determine how many gallons a minute are coming out. In measuring the rate of flow of electric current through a lamp, however, one would measure it in *amperes* by use of a meter called an *ammeter*. In the same way that a water faucet only partly open will not permit as many gallons a minute to flow, one electric light or other device may provide a smaller opening in the circuit than another and allow fewer amperes to flow.

Pressure in a water system can be measured by a pressure gauge in pounds per square inch while electrical pressure is measured in *volts*. An ordinary dry cell will give about one and a half volts while our house lighting circuits operate at a pressure of one hundred and ten volts. Voltage is measured with a *voltmeter*.

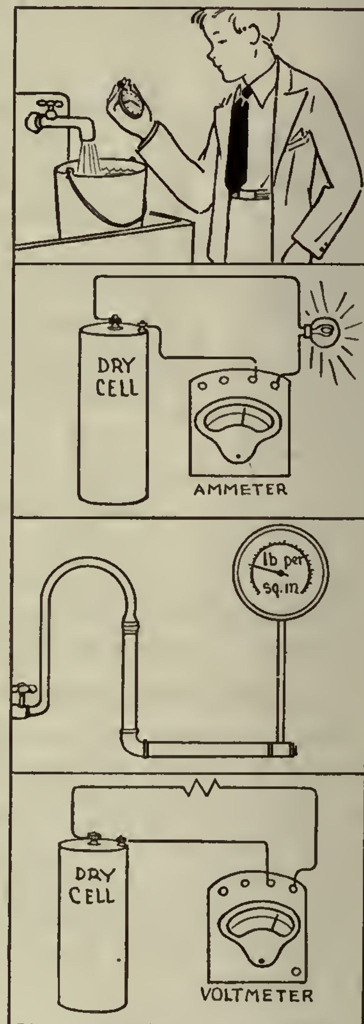


FIG. 421. COMPARISON OF MEASUREMENT OF CURRENT AND PRESSURE, WATER AND ELECTRICITY

In water currents it is of no practical value to have a unit for measuring the resistance offered to their flow by different kinds and sizes of pipe. In electrical currents, however, resistance is very important and is measured in a unit called the *ohm*. This unit is named in honor of George S. Ohm, a German scientist, while the ampere is named for A. M. Ampere, a French scientist, and the volt for Alessandro Volta, an Italian scientist.

The following table will summarize the things which you have learned about water and electric currents.

Factor	Water Current	Electric Current
Rate of current flow	Gallons per minute	Ampere
Pressure	Pounds per square inch	Volt
Resistance	No unit	Ohm

Exercise. *Carefully examine the connection of electric light bulbs where the wiring is exposed as in the basement or in the attic. Would you infer that the lights are connected in parallel or in series? Give reasons.*

Exercise. *When one bulb in a string of Christmas tree lights goes out, all others in the same string go out. Would you infer from this fact that these lights are connected in series or in parallel? Give reasons.*

What important law governs electric currents? George S. Ohm, a German scientist, discovered that electric currents, like other phenomena in nature, are controlled by certain laws which may be expressed as mathematical equations.

Ohm discovered that in any electric circuit the number of amperes flowing is always equal to the volts of pressure divided by the ohms of resistance.

$$\text{Rate of flow (amperes)} = \frac{\text{pressure (volts)}}{\text{resistanee (ohms)}}$$

An ordinary electric iron offers about 22 ohms of resistance to the current flow. Now if one wishes to know how many amperes flow when the iron is connected to a 110-volt line he uses Ohm's Law as follows:

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}}, \text{ or amperes} = \frac{110}{22} = 5 \text{ amperes}$$

An electric heater uses six amperes when connected to a 110-volt line, and if one needs to know the resistance of the heating element in ohms he uses the law thus:

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}}; \text{ therefore, ohms} = \frac{\text{volts}}{\text{amperes}}$$

$$\text{or ohms} = \frac{110}{6} = 18\tfrac{1}{3} \text{ ohms}$$

The rate at which a lamp, motor, or heater uses energy is measured in a unit called the *watt*, named in honor of James Watt of steam-engine fame. We have come to know electric-light bulbs as 40-watt, 75-watt, or 100-watt bulbs, and if you will look on the name plate of any other electrical device such as an iron, toaster, or motor, you will see marked on it a certain number of watts. These numbers merely indicate the rate at which the device uses electrical energy.

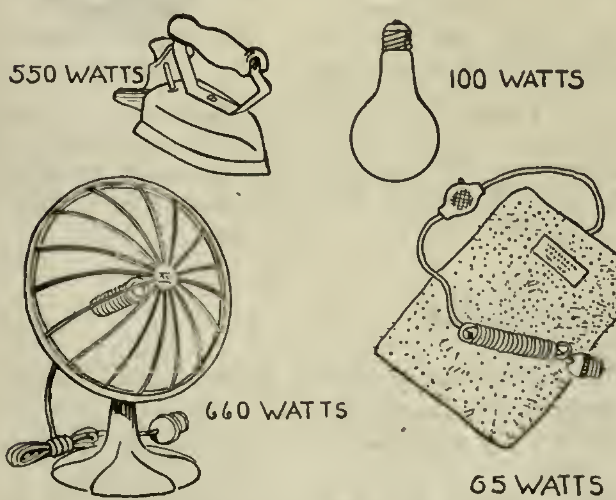


FIG. 422. DIFFERENT RATES OF USE OF ELECTRICITY

If the rate of using energy is not marked on the device in watts, it is easy to calculate when the current in amperes and the pressure in volts are known.

$$\text{Watts} = \text{volts} \times \text{amperes}.$$

For example, an electric percolator which permits five amperes of current to flow when the pressure is 110 volts would use energy at the rate of 550 watts.

$$\text{Watts} = \text{volts} \times \text{amperes, or watts} = 5 \times 110 = 550 \text{ watts}$$

Electricity is usually used at such a rapid rate in the modern home and in industry that the watt as a unit is too small for practical purposes; hence, a larger unit, the *kilowatt*, is used.

$$1 \text{ kilowatt} = 1000 \text{ watts}.$$

Thus, if an electric iron is rated at 550 watts, that means 0.550 kilowatts.

How is the cost of electricity determined? The meter which you learned to read in your experiment did not read in kilowatts but in kilowatt hours. This will be clearly understood by a simple example. If you can walk at the rate of three miles an hour, in five hours you can walk fifteen miles. You obtained this by multiplying the rate at which you walk by the total time you were walking. In a similar way, if electricity is being used at the rate of one kilowatt and it is used for an hour, the total amount of energy used will be one kilowatt hour. If an electric flatiron which uses energy at the rate of 0.550 kilowatts is used for two hours in doing an ironing it will consume 2 × 0.550 or 1.10 kilowatt hours of electrical energy. If this energy costs 10 cents per kilowatt hour the ironing will cost \$.10 × 1.10 or 11 cents.

The reading of electric meters is usually recorded once a month. When the next reading is taken, the one for the previous month is subtracted, the difference between the two being the number of kilowatt hours used in the intervening time. This is then multiplied by the price per kilowatt hour to find the amount.

Exercise. *Electricity in a certain city is sold at the rate of eight cents per kilowatt hour. Calculate the bill for a month of thirty days in a home where the following electrical appliances were used for the specified times.*

Device	Wattage rating	Number of hours used per day	Number of days used per month
1 toaster	550	1	30
10 lamps	40	4	30

6 lamps	60	2½	30
5 lamps	100	3	30
1 motor	600	3	6
1 flatiron	500	3	6
1 heater	400	2	10
1 hot plate	300	2	5
1 heating pad	200	1½	1

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Chap. 22

Clement, Collister, and Thurston, *Our Surroundings,* Chap. 15

Hunter and Whitman, *Science in Our World of Progress,* Unit 7; *Science in Our Social Life,* Unit 7

Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 23

Pieper and Beauchamp, *Everyday Problems in Science,* Unit 14

Powers, Neuner, and Bruner, *Man's Control of His Environment,* Unit 5

Skilling, *Tours through the World of Science,* Tour 10

Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 17

Watkins and Bedell, *General Science for Today,* Chap. 25

Webb and Beauchamp, *Science by Observation and Experiment,* Unit 5 (part)

Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 9

Special references

Collins, *The Book of Electricity*

Darrow, *Masters of Science and Invention*

Lunt, *Everyday Electricity*

Meister, *Magnetism and Electricity*

Morgan, *The Boy Electrician*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the units of measurement used for electrical currents.
2. How to do simple problems in Ohm's Law.
3. How to read an electric meter.
4. How to calculate the amount of energy used by an electrical device.
5. How to calculate an electric bill.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The unit of electrical pressure is the ____.

2. In a water system, current flow is measured in ____, but in an electrical system it is measured in ____.

3. The device shown in Figure 423 measures the ____ of an electric current.

4. A switch in an electric circuit corresponds to a ____ in a water circuit.

5. Water pressure ____ the farther away from the source one gets.

6. A faucet in a water system corresponds to a ____ in an electrical system.

7. The reading of the electric meter dials shown in Figure 424 is ____ kilowatt hours.

8. Ordinary house electrical circuits operate on ____ of electrical pressure.

9. To measure the current flow in an electric circuit an ____ is used.

10. Electrical power is measured in ____.

Central Scientific Company

FIG. 423

11. The consumption of electrical energy is measured in ____.

12. The unit of electrical resistance is ____.

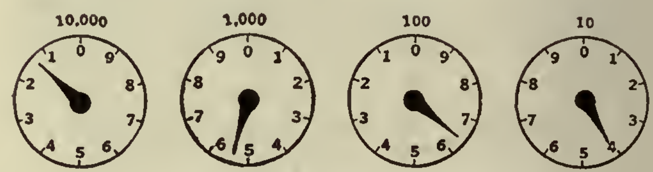


FIG. 424

13. The resistance of an electric lamp is 220 ohms. If it is used on 110 volts the current needed is ____.

14. A certain electric heater uses five amperes of current when connected to the 110-volt line. The resistance of the heater is ____.

15. The resistance of a coil of wire is sixty ohms. What voltage is needed to run ten amperes of current through it?

16. The device shown in Figure 425 is used to measure the ____ of an electric current.

17. Assume that the meter reading in Figure 424 was taken in a certain home at the beginning of a month and the reading of the meter shown in Figure 416 at the end of the month. Find the number of kilowatt hours of electrical energy consumed during the month and the monthly bill at the rate of ten cents per kilowatt hour.

Central Scientific Company

FIG. 425

SUPPLEMENTARY MATERIALS

Reading suggestions

Darrow, *Masters of Science and Invention* (Harcourt)

Darrow, *Boys' Own Book of Great Inventions* (Macmillan)

Darrow, *Boys' Own Book of Science* (Macmillan)

Gibson, *Romance of Modern Electricity* (Lippincott)

Morgan, *The Boy Electrician* (Lothrop)

Seaver, *The American Boy's Book of Electricity* (McKay)

Jones, *The Life Story of Thomas Alva Edison* (Grosset)

Greenwood, *Ambers to Amperes: the Story of Electricity* (Harper)
Gibson, *How We Harness Electricity* (Blackie & Son)
Crowther, *Osiris and the Atom* (Coward-McCann)
Anderson, *Electricity for the Farm* (Macmillan)
Adams, *Harper's Electricity Book for Boys* (Harper)

Reports which may be prepared

1. The life and achievements of Luigi Galvani
2. The life and achievements of Alessandro Volta
3. The life and achievements of Andre M. Ampere
4. The life and achievements of George S. Ohm
5. Joseph Henry and the first electromagnet
6. Faraday and his discoveries in electricity
7. Other discoveries of Faraday
8. The evolution of electric lighting
9. Edison and the electric light
10. Davy and the discovery of the electric arc
11. Benjamin Franklin, the scientist
12. Electricity on the farm
13. The making of neon signs
14. Boulder Dam and the harnessing of the Colorado River
15. New developments in highway lighting
16. Lightning rods and their use on farm buildings

Great scientists you should know about

1. Alessandro Volta
2. Benjamin Franklin
3. Luigi Galvani
4. William Gilbert
5. Joseph Henry
6. Michael Faraday
7. Hans C. Oersted
8. Thomas A. Edison
9. George S. Ohm
10. Andre M. Ampere

Investigations and things to do

1. Make a compass from a piece of steel and a cork.
2. Make a model of Volta's first "electric pile."
3. Make an electroscope.
4. Make an electric buzzer.
5. Make a small galvanometer.
6. Set up and test several types of electric cells such as the Daniell cell, the bichromate cell, the gravity cell.
7. Make working models of two types of water wheels.
8. Set up a miniature power plant with lights, bells, motors, etc.
9. Build a small electric motor.
10. Make a push button.
11. Set up a cell and electroplate with copper.
12. Make a magnet out of a hack saw blade.
13. Make a standard compass from a hack saw blade.
14. Learn how to make electrotypes.
15. Make an electric lamp.

UNIT XII. HOW MAN COMMUNICATES

Throughout the ages the advancement of civilization has been vitally dependent upon progress in two great human needs, transportation and communication. Each has developed from the crude methods of the savage to its present state of complexity. A study of the advancement of the art of communication is interesting. Prehistoric man, so far as we know, depended solely upon word of mouth delivered personally or perhaps by messenger. The more civilized ancients of Egypt, Babylonia, Assyria, and other great empires at the dawn of history developed forms of writing. As knowledge increased, messages were scratched in crude hieroglyphics upon wax and even clay and then upon parchment, but the time of delivery of the message was always dependent upon the speed of the messenger.

The ancient Aztecs, and perhaps other races, had their heliographs; the American Indian used his smoke signal; the African savage, his tom-tom code; but these and other methods of the kind were merely makeshifts for emergencies and unavailable for individual communication. The art of writing was developed several thousand years ago. Five centuries ago, Gutenberg invented printing, but it is significant of the extraordinary progress of our own times that through all the development of civilization it was not until the last century that man developed a dependable method of really rapid communication between distant points.

The advances made in communication during the last century have been remarkable: first, the telegraph by Morse, then the telephone by Bell, the wireless by Marconi, and then in rapid succession the myriad inventions including household radio receiving sets, pictures by wire, pictures by wireless, and now television in its infancy. The subject of communication is so full of possibilities and romance that everyone should want to know more about it.

When one stops to consider the tremendous importance of communication in promoting international good will and understanding, it becomes a topic of the highest importance. We want you to learn the how and why of communicating devices and also about the men who have made possible this important agency of human welfare.

What do you know about communication? Answer as many of the questions as you can.

1. What sort of communication was common during the Middle Ages?
2. What discoveries made possible the invention of the telegraph and telephone?
3. What device that you have already studied about is made use of in the telegraph?
4. Does sound travel through the wire in a telephone system? Explain.
5. What kind of electric current is used in the telegraph and telephone?
6. Of what importance is static electricity in radio?
7. Open a telephone receiver by carefully unscrewing the earpiece. What things do you recognize that you have studied about?
8. Open the radio set at home and then turn it on. What do you observe? Describe accurately the appearance of the bulb.
9. What is an electric current?
10. How are cells and batteries able to furnish electric current?

TOPIC 1. EARLY FORMS OF COMMUNICATION

SUGGESTED PROBLEMS AND QUESTIONS

What is the early history of communication?

a. **How did separated groups in ancient times communicate?**
b. **How did people communicate during the Middle Ages?**
c. **What forms of communication were used by the Indians?**
d. **How did the early American settlers communicate?**

SUGGESTIONS AND HELPS FOR STUDY

1. The nature of this topic is largely informational and will therefore demand considerable reading and study.

2. You will find a great deal of your material for this topic in history books and general references and comparatively little in science textbooks.

3. Some of the material for c and d will no doubt come out of your own experience and past reading.

4. Make a picture-graph of the development of communication, giving dates in so far as you are able. You may wish to do this on large paper to put on the science room wall.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is the early history of communication? Communication is as old as the human race. One of the things that has enabled man to develop from the savage state to that of modern civilization has been his ability to communicate with his fellow beings.

The earliest form of communication of one individual with another is not exactly known. From studies of some of the primitive tribes now living in Australia and Africa scientists believe that some sort of sign language probably aided by grunts and simple noises was the first crude form used by man. As time went on, the sign language gradually developed into a crude spoken language, and centuries later the signs again formed the basis of a crude written language.

From studies made of the skulls of the earliest men who inhabited the earth, scientists find that the portion of their brain which controlled speech was fairly well developed. This seems to indicate that the spoken word has been man's most reliable form of communication for a very long period.

As long as man dwelt in small groups and had little or no contact with other groups or tribes, the spoken word was sufficient for communication. As his needs became greater and he began to trade with other tribes and make war on them, he found that it often became necessary to send messages. Out of this need picture writing developed. A crude picture or series of pictures was used to convey a series of ideas. The pictures usually represented things but gradually came to represent sounds.

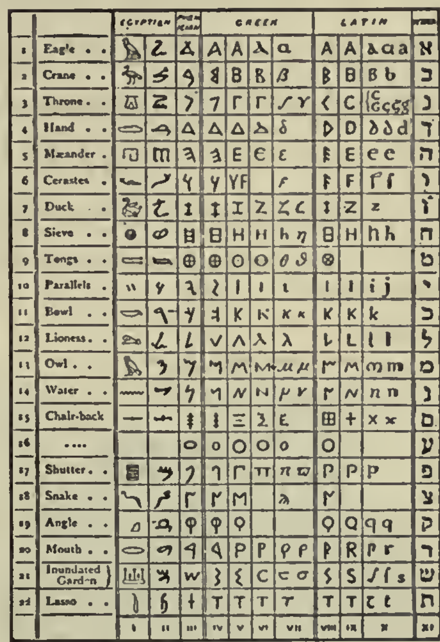
The modern alphabet as we know it has come down to us from the Phœnicians, a race of sea-going people who inhabited a portion of the eastern shore of the Mediterranean Sea about 1500 B.C. Some scientists believe that they secured the foundation of their alphabet from the writings of the Babylonians and the hieroglyphics of the Egyptians. The early Greeks, who secured their alphabet from the Phœnicians, perfected it and passed it on almost in its present form. Figure 426 shows how the alphabet has developed from picture writing.

Devices to aid in communication seem to have been developed at a very early period. Many of these may have developed as a result of the need of more speedy communication in periods of war. The ancient Greeks and Romans used relays of couriers to carry messages, and even today in the Olympic games a marathon race is run. This had its origin in the run of a Greek courier, Pheidippides, who sped from the plains of Marathon to Athens to report the Greek victory over the Persians. Legend tells that at the end of his journey the runner gasped "Rejoice, we have conquered" and dropped dead.

The Persians used shouting sentinels placed at intervals within the range of the human voice and were in this way able to send messages more rapidly because sound travels at a speed of about eleven hundred feet per second. The tom-tom signaling used by African tribes also takes advantage of the speed of sound.

The ancient Chinese built signal towers at intervals in the Great Wall and used them in times of war to pass messages.

Many of the early civilizations developed means of communicating which made use of light and the sense of sight. This usually proved more effective than those methods which depended upon sound and also had the advantage of being more rapid. The early Mound Builders of North America built high mounds



From Clodd's The Story of the Alphabet. *Courtesy of D. Appleton and Company, publishers.*

FIG. 426. DEVELOPMENT OF THE ALPHABET

used in some cases for signalling with fire. The early American Indians used fire arrows, smoke signals, and beacon fires to communicate with distant tribes. The Aztecs and Incas in Central America and South America developed the heliograph, a device which flashed messages by means of sunlight.

About 1450 A.D. communication received one of its greatest advances in the development of movable type for printing. This development was made by Gutenberg in Germany. The Chinese had used printing for several centuries before this, but Gutenberg first developed it on a commercial scale. Books were printed, and at an early date news sheets began to appear. These were the forerunners of our modern newspaper, which we recognize as one of the most important of modern communicating agencies.

Early Americans depended upon such developments as the stagecoach, the early roads, and the postal system. During the pioneer days the famous pony express, a part of the early postal system, was developed and later displaced by the growth of the railroads, one of our modern aids to communication.

The various nations of the earth have developed

elaborate systems of signal communication, which are used chiefly in times of war. By these methods messages are sent in code.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Unit 9
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 17 (part)
Hunter and Whitman, *Science in Our World of Progress,* Unit 10
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 25
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 16
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 18
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 2
Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 12

Special references

Beeby, *How the World Grows Smaller*
Earle, *Stage Coach and Tavern Days*
Nida, *Following the Frontier*
Marshall, *The Story of Human Progress*
Fairbanks, *The Western United States*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. What some of the ancient forms of communication were.
2. How communication developed as civilization advanced.

TEST OF MASTERY OF THE TOPIC

In your notebook answer the questions and comply with the instructions.

1. What people used the heliograph as a means of communication?
2. List some of the forms of communication of the American Indian.
3. Write a paragraph showing how a great discovery made by Gutenberg influenced the communication of the Middle Ages and after.
4. Make a list of all the ancient forms of communication which you have discovered and give the name of the people or country responsible for the development of each, in so far as you are able.
5. When, in your judgment, did the era of modern communication begin?
6. List the discoveries which led to the era of modern communication.
7. List as many devices as you can which are used today for communication.
8. Cite some incident from your own experience in which you would have been greatly handicapped or endangered had you been living in the Middle Ages and had not had the convenience of modern methods of communication.
9. List as many ways as you can in which modern methods of communication have changed our ways of living.
10. Can you suggest some of the problems that have been created as a result of modern communication?

TOPIC 2. COMMUNICATION BY TELEGRAPH

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is the early history of the telegraph?**
2. **What are the parts of a simple telegraph system and how are these parts connected into a telegraph circuit?**
3. **How are messages sent long distances on land and under sea by telegraph?**

SUGGESTIONS AND HELPS FOR STUDY

1. Become thoroughly familiar with the problems stated before you attempt their solution.

2. Be sure to understand the construction of the telegraph key, sounder, and relay.

3. Get all the experience you can in connecting the various instruments, as this will greatly aid your understanding of the topic.

4. You can pass Boy and Girl Scout tests by knowing the Morse code. It can be easily learned by means of the telegraph.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 162. How do the telegraph key and sounder work?

If telegraph instruments are not available for this experiment, they can be very simply made like those shown in Figure 427. The key is made from two strips of copper and a spool which has been cut in two pieces, one for the key-bar and the other for the switch. The sounder is made from a cigar box, screw eyes, and bolts. The electromagnet is made by winding several hundred turns of wire on the bolt, which is fastened in an upright position.

Connect the instrument as shown in the illustration with one or two dry cells. Study the set-up carefully and send dots and dashes by means of the key. Trace the current through the instruments. Close the switch on the key and note what happens.

In your notebook record notes of the experiment and complete the following statements.

The key is a device used to ____ and ____ the circuit. When the key is down, ____ flows in the circuit, magnetizing the ____ of the sounder and causing it to pull the ____ bolt up, making a ____. The bar of the sounder drops back when the ____ is opened, and the ____ loses its ____.

[1] See workbook, p. 96.

The switch on the key allows ____ to flow around the contact points, closing the ____ through the key.

Experiment 163. How are messages sent over long distances by telegraph?

For this experiment you will need two keys, two sounders, and three or four dry cells. String a wire from one

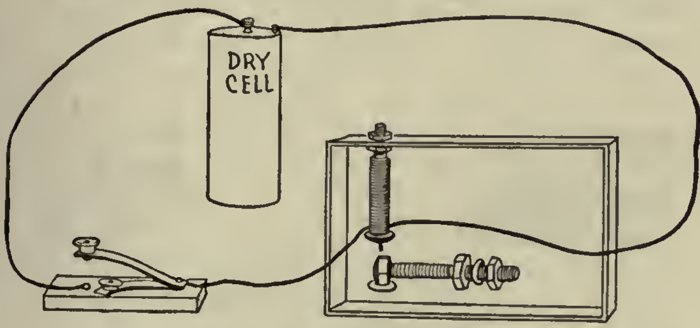


FIG. 427

end of your room to the other and connect the instruments and batteries as shown in Figure 428. Instead of a return wire connect the instruments at either end to a radiator or water pipe.

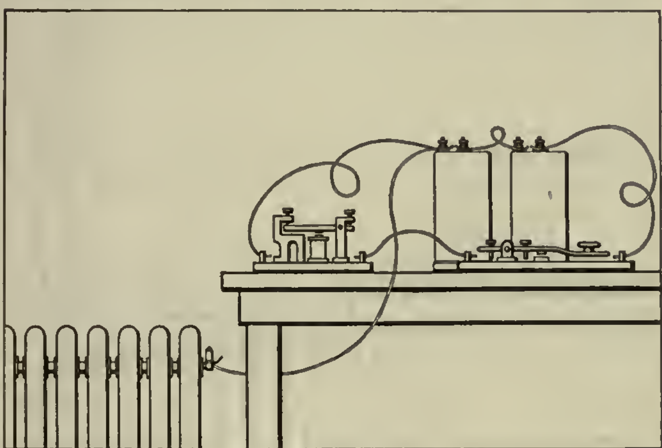


FIG. 428

Close the key-switch at the end of the line where the first message is to be received and leave the switch open at the sending end. Have your partner send to you and then by changing the switch at each end you may send to him. Study the set-up carefully and trace the current through all the instruments.

Write a paragraph carefully summarizing the important conclusions to be drawn from this experiment.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. If a telegraph relay is available, connect it in one end of the telegraph line used in Experiment 163.

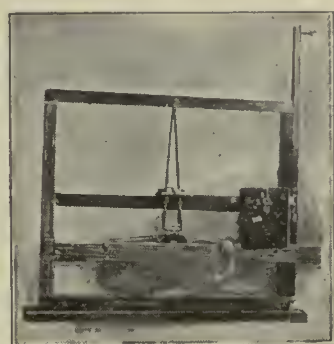
2. Visit a telegraph office and examine the equipment used.

3. Devise an experiment to prove that the earth is a conductor of the electric current. Test your experiment.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is the early history of the telegraph? As early as 1684 Robert Hooke, an English scientist, had devised a scheme for aerial communication. In his scheme, towers were built on hills several miles apart and messages were sent by pulling the letters of the alphabet to the tops of these towers. The telescope was used in reading the letters, and in this manner messages could be sent from station to station. Over a hundred years later, during the French Revolution, Chappe, a Frenchman, worked out a plan of semaphore signaling. This made use of arms placed on a high tower. These arms could be set at different angles by means of cords. Chappe worked out a code in which different positions of the arms represented different letters of the alphabet. By 1800 this system was used extensively over France for purposes of communication between cities. Messages could be sent at about 100 words per hour.

In 1748 Benjamin Franklin had been able to send an electric discharge through a wire across the Schuylkill River at Philadelphia and had thought of the pos-



Courtesy Western Union

FIG. 429. MORSE'S TELEGRAPH INSTRUMENTS

sibilities of using electricity for purposes of communication, but too little was then known about this mysterious force. By 1800 Galvani and Volta, Italian scientists, had made their discoveries which made possible the electric battery. The next quarter century saw the discovery of the magnetic effect of the electric current by Oersted; the series of discoveries by Sturgeon in 1825, Faraday about 1830, and Henry about 1831 perfected the electromagnet. All of these discoveries were necessary to pave the way for the invention of the telegraph.

The invention of the telegraph. The use of electricity for communication had been thought of by Franklin and later had been worked out in the laboratory by Joseph Henry in Albany, N.Y., about 1831. In 1832, while returning to America by ship, Samuel F. B. Morse, an artist and teacher, began to think of the possibilities of using the electromagnet in communication. Giving up a career in art, he devoted himself and all of a small fortune to perfecting a telegraph.

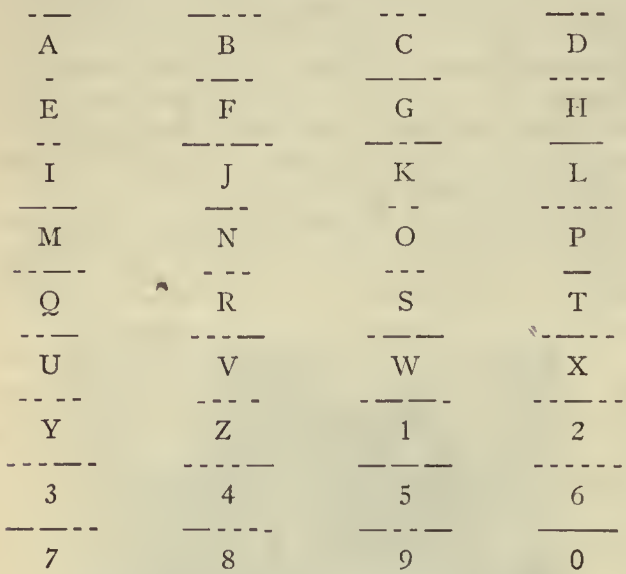


FIG. 430. AMERICAN MORSE CODE

By 1843, working with Alfred Vail, Morse had completed his invention and was ready to give it to the world. He had worked out a code consisting of "dot" and "dash" combinations to represent letters of the alphabet which is still used in modern telegraphy.

Morse secured a grant of $30,000 from the United States in 1843 and at once set about the construction of a telegraph line between Baltimore and Washington. On May 24, 1844, Morse sent these memorable words, "What hath God wrought," from Washington to Vail, seated forty miles away in Baltimore. From this small beginning the telegraph has developed into one of our most important devices for communication.

What are the parts of a simple telegraph and how are these parts connected into a telegraph circuit? In one of the experiments which was performed in the unit on electricity you worked with electromagnets. How did the electromagnet act when electric current was flowing through its coil? What happened when the current was turned off? The telegraph is made of two devices, a key or sender and a sounder or receiver. These are shown connected with a battery by a wire in Figure 431. The key is used to close and open the electric circuit much as a switch. When the key is pressed down the circuit is completed and current flows from the battery through the key and sounder and back to the battery. When the key is released it is pushed open by springs, thus breaking the circuit and stopping the flow of current from the battery.

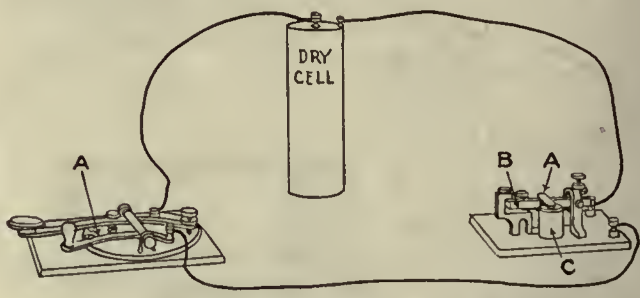


FIG. 431. TELEGRAPH SOUNDER AND RECEIVER

The sounder is made of an electromagnet over which is mounted an iron bar. The bar is pulled down by the magnet when current flows through its coils and is drawn back by a spring when the current is not flowing. As the bar is drawn down it makes a

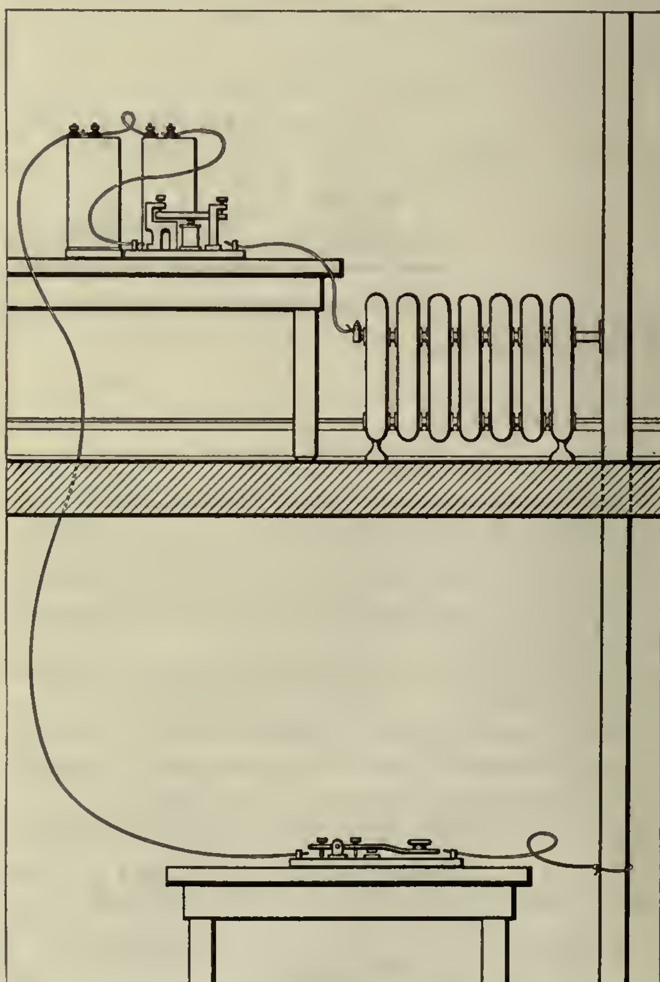


FIG. 432. ONE-WAY TELEGRAPH BETWEEN ROOMS

click which can be easily heard. On some sounders part of the bar is made of aluminum to make it light. This moving bar is called the *armature*.

The simple telegraph shown in Figure 431 has a complete circuit of wire. If a single wire were strung from one room to another, a key, sounder, and battery might be connected as shown in Figure 432. Notice that a wire from the key and one from the sounder are connected to a water pipe. In this way the electrical circuit is completed through the metal water pipes of the building. Connection may be made to the pipes of the heating system. In long distance telegraphy the earth is used as a return, and only one wire needs to be used. This makes for a great saving in cost of wire and line construction.

If a key and a sounder are to be placed at each end of the circuit it may be arranged as shown in Figure 428. The water pipe is again used as a return. When such a system as this is assembled it is evident that each key makes an opening in the circuit and no message can be sent unless one of the keys is held down while the other is used in sending a message. This might prove difficult; hence, all telegraph keys have a switch which is closed when a message is being received but open when the key is being used for sending.

How are messages sent long distances on land and under sea by telegraph? In your study of the unit on electricity you learned that long wires give more resistance to the flow of an electric current than shorter ones of the same size.

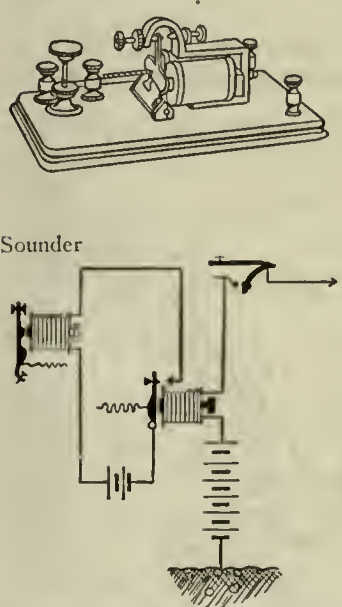


FIG. 433. A RELAY AND HOW IT IS CONNECTED

When a telegraph line is more than 350 miles in length, the current from batteries or even dynamos is too feeble to operate the sounder because of the resistance. This difficulty is overcome by using a device called a *relay*. Figure 433 shows a relay, and how it is connected in a telegraph line.

The relay is a combined instrument, part of it working like a very sensitive sounder and part like a key. Let us study its construction and workings. The sounder-like part of the instrument is made up of two electromagnets which are wound with many turns of fine wire. The feeble line currents, too weak to operate a sounder, are passed through these coils. The feeble currents going through so many coils make sufficient magnetic force to attract the armature or moving part. How does the armature of the relay seem to compare in weight with that of a

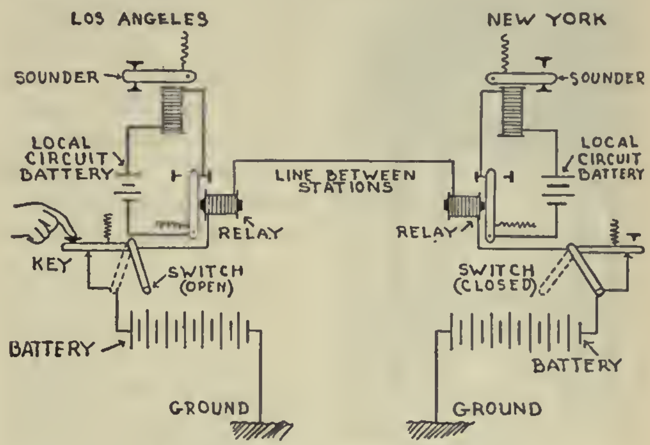


FIG. 434. COMPLETE TELEGRAPH SYSTEM

sounder? Would this help to make the instrument more sensitive than a sounder? The armature of the relay, unlike that of the sounder, is not constructed to make clicks but to act as a key. The armature of the relay is connected into another electrical circuit (see Figure 433) with a battery and sounder. The feeble line currents do not reach this circuit, for they pass around the relay electromagnet from the line and then out to the return wire or ground.

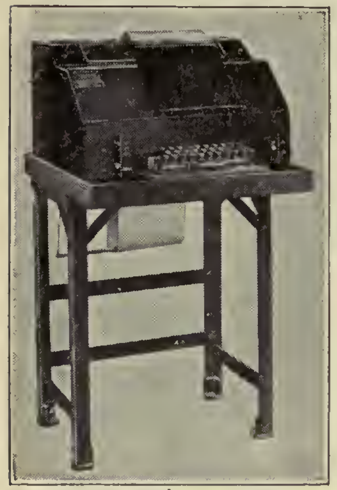
As the armature of the relay is pulled up by the electromagnets, it closes the little local circuit just as a key would. This permits current from the local battery to flow and operate the sounder. The armature of the sounder works exactly with the armature of the relay, making dots and dashes as they come over the line wire. Figure 434 shows a diagram of a complete telegraph system with key sounders, relays, and batteries between two large cities. Study the diagram carefully and see if you can answer the questions.

At which end of the line is the message being sent? How can you tell? How does the current get back for a complete circuit when there is only one line wire? What changes would be made if the operator at the end of the line sending wished to receive a message from the other city? When New York is sending, can the operator hear his own message as he sends it? Does the line current get into the local circuits? Explain your answer.

If you were to go to a modern commercial telegraph office you no doubt would be surprised to see how the messages are actually sent and received. The older style key and sounder have been replaced by automatic devices which make it possible to send and

receive messages much more rapidly.

In one type of sending instrument the operator has a keyboard before her similar to the one on a typewriter. Messages are sent by pressing the keys. A receiving instrument in a distant city is connected with this sender and the message is typed automatically. Figure 435 shows an instrument of this type. In another modern instrument the depression of keys cuts perforations in a tape which is later fed through an automatic sending instrument. Figure 436 shows the cutting of this tape.



Bell Telephone Laboratories

FIG. 435. TELETYPEWRITER

Courtesy Western Union

FIG. 436. CUTTING TAPE FOR AUTOMATIC SENDING INSTRUMENT

Modern telegraphy is of great importance to all of us. There are more than 6,500,000 miles of land and ocean telegraph lines in the world. Not only is it possible to send messages but money, photographs, and letters in handwriting. Stock quotations are telegraphed to and from all parts of the world, while the modern newspapers could hardly be produced without the aid of the telegraph.

Great ocean cables now join all of the continents of the world and make possible rapid telegraph communication between them. Figure 437 is a map showing the principal cables of the world and Figure 438 shows a section of the newest type of ocean cable.

FIG. 437. OCEAN CABLES

The application of scientific principles has made it possible for telegraph companies to save millions of dollars in the construction of lines and equipment. By using certain methods and certain instruments it is possible to send two, four, or eight messages over a single wire at the same time. A system in which two messages are sent at the same time is called a *duplex* and one in which four messages are sent is a *quadruplex* system.

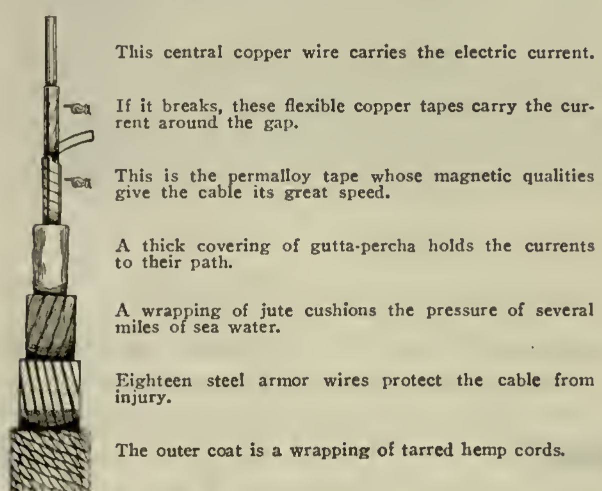
REFERENCES FOR FURTHER STUDY

Texts

- Caldwell and Curtis, *Science for Today*, Unit 9
- Clement, Collister, and Thurston, *Our Surroundings*, Chap. 17 (part)
- Hunter and Whitman, *Science in Our World of Progress*, Unit 10
- Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 25
- Pieper and Beauchamp, *Everyday Problems in Science*, Unit 16
- Skilling, *Tours through the World of Science*, Tours 11 and 12
- Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 18
- Webb and Beauchamp, *Science by Observation and Experiment*, Unit 2
- Wood and Carpenter, *Our Environment: How We Use and Control It*, Topic 12

Special references

- Meister, *Magnetism and Electricity*
- Morgan, *The Boy Electrician*
- Seaver, *The American Boy's Book of Electricity*



Courtesy Western Union

FIG. 438. NEW TYPE OF CABLE

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Know the construction and operating principle of the telegraph key, sounder, and relay.
2. Acquire skill in connecting these devices into a complete telegraph circuit.
3. Know something of modern telegraphy and how it is carried on.
4. Know how telegraph messages are sent across the ocean by cable.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Explain briefly how an electromagnet differs from a permanent magnet.

2. The key in a telegraph circuit is used to ____.

3. The device shown in Figure 439 is called ____.

4. The part marked *A* is made of ____ because it must be a ____ substance.

5. The ____ are shown at *C*.

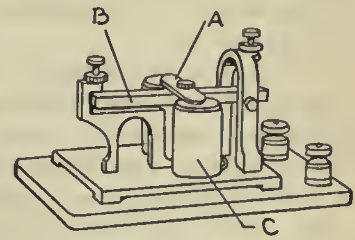


FIG. 439

6. The bar marked *B* is made of ____ because it is a ____ metal.

7. The device in Figure 440 is called a ____ and is used to ____.

8. What is *A* and what does it do when the device is operating?

9. Make a sketch drawing showing a key, sounder, and battery at each end of a telegraph line which uses only one wire.

10. Make a sketch drawing of a relay and local circuit showing how the connections are made.

11. Can more than one message be sent over one wire at a time? Explain.

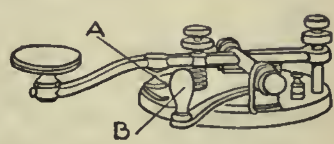


FIG. 440

12. Does the relay strengthen the electric current which comes to it? Explain.

13. Explain how the relay differs in construction and use from the telegraph sounder.

14. What are some of the modern devices used by telegraph companies?

15. In making a home telegraph set a boy decided that he could prevent magnetic loss in his set and therefore make the magnet stronger by winding insulated iron wire on a brass bolt and by using brass parts throughout. Criticise his method and tell how he should have built the set.

16. In a commercial telegraph circuit the ____ is used as a return circuit.

17. Suggest the reason why the switch on the telegraph key must be open when messages are being sent from that instrument.

18. Where does the energy come from that operates the sounder in the local circuit of a telegraph system having a relay?

19. Why must code signals be used in sending telegraph messages?

20. Where does the energy come from that operates the relay in a telegraph circuit?

TOPIC 3. THE TELEPHONE IN COMMUNICATION

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is the early history of the telephone?**
2. **How does the electric bell work?**
3. **How does the telephone transmitter work?**
4. **How does the telephone receiver work?**
5. **What happens at the telephone central?**

SUGGESTIONS AND HELPS FOR STUDY

1. Become thoroughly familiar with each problem as stated before attempting any reference study or investigation of it.

2. A trip to a telephone central will serve to help you understand many of the interesting things which go on there and will also teach you many of the problems confronted in such an office.

3. The study of the operation of a dial telephone is very interesting. It will teach you how man has been able to reduce the labor of human hands through electricity.

4. You may find the following new words and phrases in this topic:

compress—to squeeze together.

diaphragm—a disk which vibrates.

grounded circuit—a pathway for electricity where the ground is used instead of a return wire.

vibration—a to-and-fro movement like that of a pendulum.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 164. How is the telephone transmitter constructed and how does it work?

Secure two pieces of copper or other metal about four inches square. Punch a hole near the edge of each piece with a nail and attach a two-foot length of bell wire as shown in Figure 441. Break the carbon rod from an old

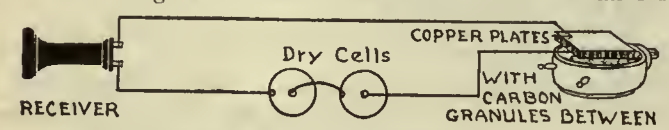


FIG. 441

dry cell into pieces about the size of a small pea. Pick out a handful of pieces that are uniform in size to use in the transmitter which you are making.

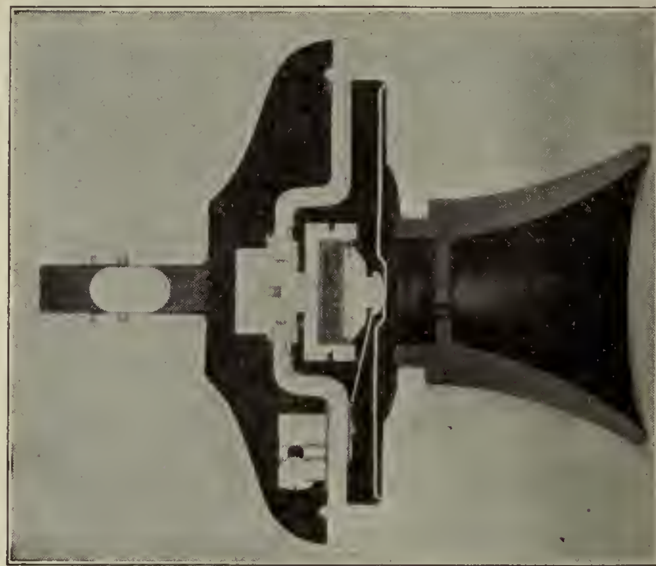
Place one of the copper plates on the glass face of an alarm clock and lay the carbon particles around on the plate. Place the other copper plate over the carbon, being careful that the plates touch neither the metal part of the clock nor each other. Connect the wires from the plates through a telephone receiver and one or two dry cells. What do you hear in the receiver?

Study the cross-section diagram of a telephone transmitter in Figure 442 and compare its parts with those of the one which you have built.

Remove the rubber mouthpiece from a telephone transmitter and while holding your ear close, press the exposed diaphragm lightly with the rubber eraser of a pencil. Can you hear the grating of the carbon particles?

In your notebook record your notes and list the conclusions which might be drawn from the data of this experiment.

[1] See workbook, p. 97.



Courtesy Bell Telephone Laboratories

FIG. 442. CROSS SECTION OF TRANSMITTER

Experiment 165. How is the telephone receiver constructed and how does it work?

Carefully unscrew the rubber earpiece on the end of the receiver shell. Find the diaphragm made of thin metal and remove it. If possible slide the shell back on the lead wires and expose the inside of the receiver. Let these questions guide your observation. How many wires lead into the receiver? Where do they appear to go? What appears to be on the earpiece end of the receiver close to the metal disk? How many of these are there? What seems to make up the back part of the receiver? Test it by bringing an iron tack near it. Bring the metal disk to the place from which you first removed it. What holds it in position? Can you suggest what might make this vibrate?

In a short paragraph clearly summarize what you have learned from this experiment.

Devise an experiment to test whether a telephone receiver can be used as a transmitter. Test your experiment.

Experiment 166. How may a telephone line be set up?

The diagram (Fig. 443) suggests two ways which you can use in the laboratory. Set up both if your time will permit.

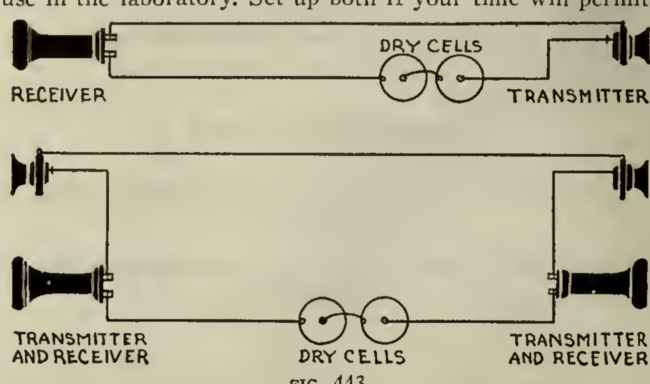


FIG. 443

Experiment 167. How does the electric bell work?

Remove the metal box cover from an electric bell and study the construction. Connect the bell with a dry cell and a push button as shown in Figure 445. Study the motion of the clapper. What causes it to move toward the electromagnets? What causes it to fly back? Why does it repeat this? Trace the current through the bell.

Summarize your results of this experiment in a short, clearly written paragraph.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is the early history of the telephone? The invention and development of the electric telegraph opened the way for the next step in communication, which was to send the human voice over wires as electric currents. In 1854 Charles Bourseul outlined a method by which he thought that speech could be sent by wire. In 1861 a German, Phillip Reis, designed a device which would transmit a tone but not the variations of the human voice.

Courtesy Bell Telephone Laboratories

FIG. 444. BELL'S FIRST TELEPHONE

The telephone was invented in Boston by Alexander Graham Bell, a young Scotchman who came to this country in 1871. Being a teacher of deaf mutes, he was greatly interested in sound and especially in the human voice. Bell had experimented with a device called the "harmonic telegraph" with which he hoped to send several messages by telegraph over one wire at the same time. Out of this harmonic telegraph the first telephone was developed.

In the course of his experiments Bell made the acquaintance of a young machinist-instrument maker by the name of Watson, who made the first instruments after Bell's plans. On June 2, 1875, these two were experimenting with the harmonic telegraph in an attic; Watson was in one room with the sending instruments, and Bell was in another room with the receivers. An accidental touch of one of the senders by Watson caused a sound to be sent over the wire to the next room, and this sent Bell running in. He asked, "What did you do then?" Watson showed him; it was repeated many times that day, and the principle of the first telephone was born. A few days later with improved instruments Watson was able to hear Bell's voice over the wire. On March 10, 1876, Bell spoke those memorable words, "Mr. Watson, please come here; I want you," which sent Watson bounding up two flights of stairs. The transmitter and receiver of this first telephone worked very much like a modern telephone receiver. A telephone line which uses only receivers may be set up. When a person speaks into one receiver he can be heard through the other.

Professor Bell exhibited his telephone in the summer of 1876 at the Centennial Exposition in Philadelphia, but it was not well received. Many practical men of the day believed it only a toy. They saw for it no future in the social and industrial life of the world. Great difficulty was found in interesting people in investing money in the new company or even in using the discovery in business. In 1877 there were only 234 telephones in the whole country. There are now about twenty million in this country alone.

How does the electric bell work? The electric bell is a very important part of any telephone system and so should be thoroughly understood. In an experiment at the beginning of this topic a study was made of the electric bell in which it was connected in a circuit with a push button and switch. When the button was pushed, current from the battery flowed through the complete circuit and the bell rang. Study the diagram in Figure 445 and see how the electricity is able to ring the bell. *A* and *B* are electromagnets, *G* is the armature or moving part, *D* is a contact point, and *E* is a spring. When the button is pushed, current flows from the battery to the electromagnets, which pull the armature *G* toward them. The circuit is broken at *D* because the spring *F* has been pulled away from the contact. When the circuit is broken no electricity flows and the electromagnets lose their power of attraction. The armature is moved backward by a spring at *E* until contact is again made at *D*. This again completes the electrical circuit, current flows, and the magnets again pull the armature and spring away from the contact. This process, repeated many times

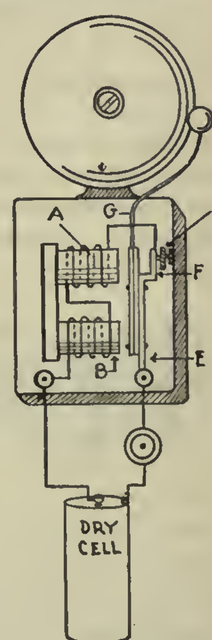


FIG. 445

a second, causes a rapid vibration of the armature and a continuous ringing of the bell.

Exercise. *Devise a method by which the electric bell could be made to give only one tap when the current is turned on, instead of ringing continuously. Suggestion: Experiment with connections at various points on the bell.*

How does the telephone transmitter work? Many people believe that sound is carried over the wire in some mysterious way. Figure 449 shows a simple telephone circuit with battery transmitter and receiver. The sound waves, carried by the air, are changed into electric currents by the transmitter. The electric currents, which are streams of negative electrical particles called electrons, are carried through the wire to the receiver, which changes them back into sound waves like those which entered the transmitter.

The voice sets up vibrations in the air. As one speaks, the molecules which make up the air are set in vibration by the variations of the voice. If a single tone or a series of tones or words is spoken, there will be a series of places where the air particles or molecules are crowded together, each place being followed by one where the particles are not crowded. Such a series of crowded and uncrowded air molecules makes up a train of sound waves. As sound waves strike the eardrum they set it in vibration. These vibrations are communicated to the brain, and we have the sensation of sound.

The telephone transmitter is a very sensitive electrical ear. Just back of the familiar mouthpiece of the transmitter is a very light and sensitive diaphragm which vibrates much as the human eardrum when sound waves strike it. The first diagram in Figure 446 shows how the crowded part of a sound wave

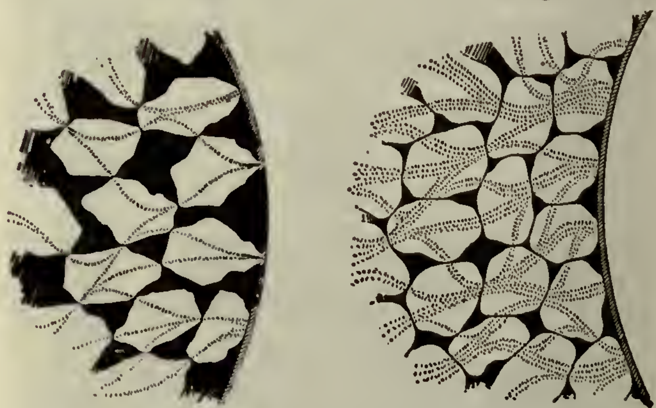
Courtesy Bell Telephone Laboratories

FIG. 446. ACTION OF SOUND WAVES ON TRANSMITTER DIAPHRAGM

pushes the transmitter *diaphragm* outward; the other drawing shows the same diaphragm a fraction of a second later when it has sprung back because an uncrowded part of the sound wave cannot push as hard as the crowded part.

Just behind the sensitive diaphragm is a little box which is partly filled with tiny pieces of roasted carbon. When the diaphragm is pushed in, these little pieces of carbon are crowded together. When the diaphragm springs back, they are loosely arranged. A stream of electrons (electric current) from a battery flows continuously through the transmitter and the carbon particles. Figure 447*a* shows an enlargement of a part of the little carbon box, the diaphragm, and the particles. The lines through the particles represent possible pathways for the electrons of the electric current and show that when the particles are loosely packed only a small current can flow through the transmitter. Figure 447*b* is an enlargement when the diaphragm has been pushed in by the crowded part of a sound wave, thus packing the carbon particles more closely together. This provides many more pathways through the particles for electrons and thus lets more current flow. As the crowded and uncrowded parts of a sound wave move up to the diaphragm, causing it to move in and out, the carbon particles are first close together and then loosely arranged. This allows first a large and then a small number of electrons to get through the carbon grains and sets up an electric current which is varying like the sound wave spoken into the transmitter.

How does the telephone receiver work? From the experiment at the beginning of this topic you will recall that the receiver has a horseshoe magnet with

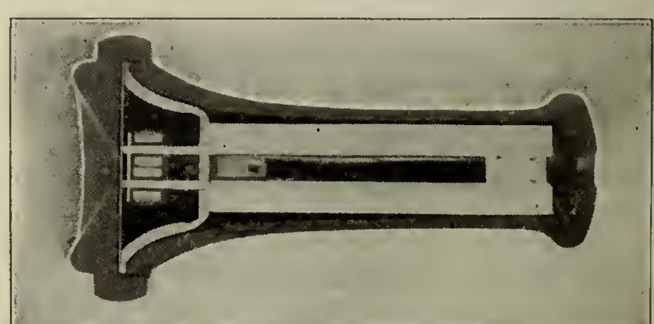


a *b*

Courtesy Bell Telephone Laboratories

FIG. 447. ELECTRON PATHS THROUGH LOOSELY AND CLOSELY PACKED CARBON PARTICLES

an electromagnet wound upon each pole. The horseshoe magnet holds a thin diaphragm, made of a magnetic substance, close to the electromagnets (Fig. 448). The line wires lead to the electromagnets of the receiver.



Courtesy Bell Telephone Laboratories

FIG. 448. CROSS SECTION OF TELEPHONE RECEIVER

As current flows into the electromagnets, they attract the thin diaphragm, bowing it toward them. When the current is lessened the attraction of the electromagnets is lessened and the diaphragm springs back. Vibrations of this diaphragm set the air particles near it in vibration, causing sound waves to be sent out.

When the varying electrical currents come over the line from the transmitter, a varying attraction is set up in the electromagnets of the receiver. The iron diaphragm is made to vibrate with the variations of the electric currents in the wire. Sound waves are thus sent out from the receiver which are similar to those that were spoken into the transmitter and that caused the varying electric currents or waves to flow over the wire.

Courtesy Bell Telephone Laboratories

FIG. 449. SIMPLE TELEPHONE CIRCUIT

Exercise. *Refer to Figure 449 and explain in detail the function of each part shown and how it works to make possible sending the voice by wire.*

What happens at the telephone central? The remarkable development of the telephone system would have been impossible without the invention and development of the switchboard. This device makes it possible for one to raise the receiver from its hook and be connected with anyone in the same city or a distant city who has a telephone.

Courtesy Bell Telephone Laboratories

FIG. 450. MODERN TELEPHONE SWITCHBOARD

There are several types of telephone switching equipment in use:

The magneto or local battery system. This type of switching equipment is used largely in rural communities because it has been found to be dependable and serviceable. Batteries which furnish current for talking are contained within each telephone. Current for signaling the central operator is generated by a hand generator also contained within the telephone. A turn of a small crank generates sufficient current to signal the operator.

The central battery system. In this type of switching, current both for ringing the bells and for talking is furnished from batteries and generators located in the central station. The lifting of the receiver causes a small electric lamp to light on the switchboard in front of the central operator.

Automatic switching devices. In many large cities automatic devices are being used to displace the central operator. In this system connection between parties is made by several complicated mechanical devices. In some places a combination of the operator and automatic systems is in use.

Figure 450 shows a switchboard in a modern central station.

Every large city is divided into districts for telephone purposes. Each of these districts has a name like "Main," "Central," or "Republic," and each has a central station. Each central station is connected with every other one in the city by several telephone lines called "trunks."

If you wish to talk with someone located in your telephone district you take the receiver from the hook. This lights a little lamp on the switchboard in front of an operator at the central station. Before her are several short lengths of flexible telephone cord with plug-like devices called "jacks" on the ends. She inserts a jack in an opening beside the lamp signal and answers you. When you give the number desired she plugs the other end of the flexible cord into the little opening which leads out to the telephone with which you wish to speak. After the jack has been placed in the proper opening, she sends a ring signal over the wire to call your party to the telephone.

If you wish to talk into another telephone district or to a distant city, the operator connects you over a trunk line with a central office in the district or city to which you wish to speak. An operator in this district or city then rings the bell of the telephone with which you are to be connected.

Within recent years much progress has been made in the advancement of telephone engineering. The dial telephone has made it possible to make a large portion of the switching automatic in the central stations where it is used. Figure 451 shows a picture of a modern dial telephone. The teletypewriter is also a modern device which combines two essentials of any office, the telephone and the typewriter. It is a carrier of written conversation. It is similar to the ordinary typewriter and is operated in the same way. Words typed on a machine in one office are recorded

Courtesy Bell Telephone Laboratories

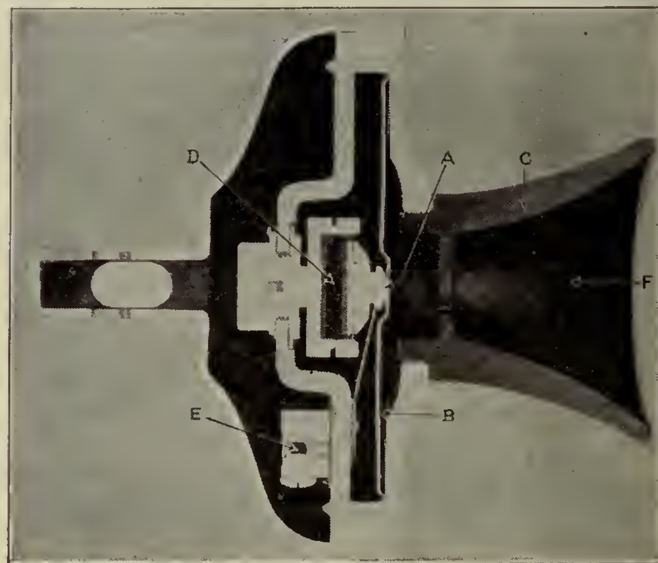
FIG. 451. MODERN DIAL TELEPHONE

on a machine connected with it in another office or another city. These devices are used by large news agencies, brokers, and police departments. One machine operated in New York may transmit messages at the same time to machines in Boston, San Francisco, New Orleans, and St. Louis. It is now possible to telephone from your home to many parts of Europe and to South America. It is also possible to send photographs over wires. You will learn of these last two achievements later in this unit.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Unit 9
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 17 (part)
Hunter and Whitman, *Science in Our World of Progress,* Unit 10
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 25
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 16
Powers, Neuner, and Bruner, *Man's Control of His Environment,* Chap. 23
Skilling, *Tours through the World of Science,* Tours 11 and 12
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 18
Watkins and Bedell, *General Science for Today,* Chap. 26
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 2



Courtesy Bell Telephone Laboratories

FIG. 452

Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 12

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The Story of a Great Achievement
Things Worth Knowing About the Telephone
How to Use the Dial Phone

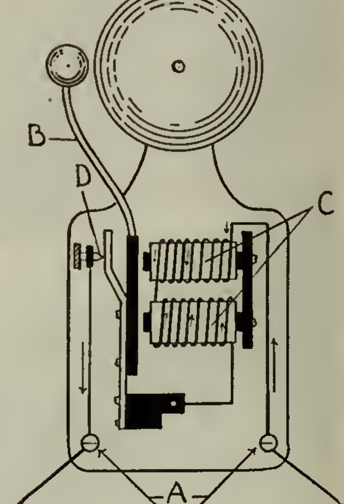


FIG. 453

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

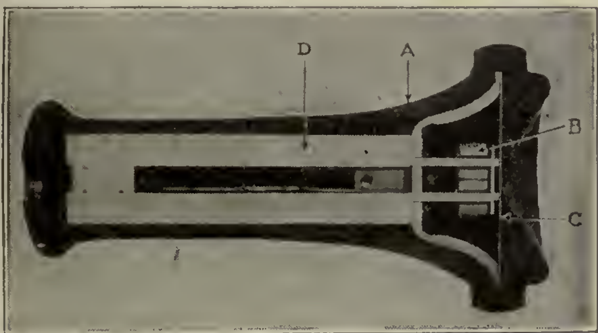
1. Something of the history of the telephone.

2. How the telephone transmitter works.
3. How the telephone receiver works.
4. What happens at a telephone central.
5. An attitude toward the importance of the telephone in everyday life.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. Explain in detail how a sound wave is changed into an electric current by the telephone transmitter.



Courtesy Bell Telephone Laboratories

FIG. 454

2. Some of the parts in the cross section of a telephone transmitter (Fig. 452) are lettered. In your notebook indicate the part which each letter represents.

3. The parts of the electric bell in Figure 453 are lettered. Name the part which each letter represents.

4. ____ travel over the wire in a telephone system.

5. ____ invented the electromagnet.

6. ____ invented the telephone in ____.

7. In the cross section of the telephone receiver in Figure 454, some of the parts (electromagnet, permanent magnet, shell, and diaphragm) are lettered. Indicate the part which each letter represents.

8. Explain the importance of each of the following parts in the receiver: permanent magnet, electromagnet, disk.

9. In the telephone transmitter the disk is made of aluminum, while in the receiver it is a thin magnetic alloy. How do you account for this?

10. Write a paragraph on "What takes place at the telephone central."

11. What sort of current is used in a telephone system to carry the messages?

12. What kind of current is used to ring the bell?

13. Would it be possible to make use of a bar or horseshoe magnet in an electric bell? Explain.

14. A sound wave is made up of a series of ____ and ____.

15. Write a summary paragraph pointing out the importance of telephone communication in modern life.

TOPIC 4. TELEGRAPHING WITHOUT WIRES

SUGGESTED PROBLEMS AND QUESTIONS

1. **What common experiences have you had with waves?**
2. **How are wireless waves set up and messages sent?**
3. **How are electric waves and messages received without wires?**

SUGGESTIONS AND HELPS FOR STUDY

1. This topic deals with sending telegraph code messages without the aid of wires. In this respect it should not be confused with radio, where the human voice is sent without wires.

2. Study the problems and see if you are interested in them or if they are worth while to you.

3. In handling the induction coil of the sending set while it is turned on, be very careful not to touch the wires leading to the aerial or the ground, as a severe electric shock will result.

4. In the study of this exercise you may find the following new words and phrases:

aerial—the part of a radio receiving or broadcasting set which is usually elevated in the air to send out or receive radio waves.

ether—a medium assumed by science to carry light, heat, and radio waves. It is assumed to fill all space, even between the molecules of matter.

wave length—the distance from the top of one wave to the top of the next one.

cohere—to cling together.

electromagnetic waves—waves which travel through the ether.

frequency—the number of vibrations per second which the ether wave is making.

induction coil—a device which changes a low voltage direct current into a high voltage current.

primary circuit—the circuit on the induction coil which contains the batteries.

secondary circuit—the high voltage circuit of the induction coil.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 168. How may wireless messages be sent?

Caution: The high voltage of the spark coil is dangerous. Be careful.

A spark coil is needed for this experiment. This can be secured from an automobile (some types) or from any mail-order or scientific apparatus house. The key used in the experiment on the telegraph may also be used here.

Connect the key, a knife switch, and batteries into the circuit as illustrated in Figure 455. Be sure that the switch is open. Lead a wire from each of the secondary or high voltage binding posts to make a spark gap of about a quarter inch. Also lead a wire from one secondary binding post to the aerial and from the other one to a ground connection such as a water pipe or radiator.

The vibrator on the coil may need adjustment; if so,

[1] See workbook, p. 100.

the adjustment can be made by means of the nut in front of it.

When the set-up is complete, have it carefully checked by the instructor before you close the switch. Dots and dashes may be made by pressing the key which closes and opens the circuit at the will of the operator. When the key is closed a spark should jump across the spark gap in the secondary coil if the coil is properly connected and adjusted. Record your notes on the experiment and complete the following statements.

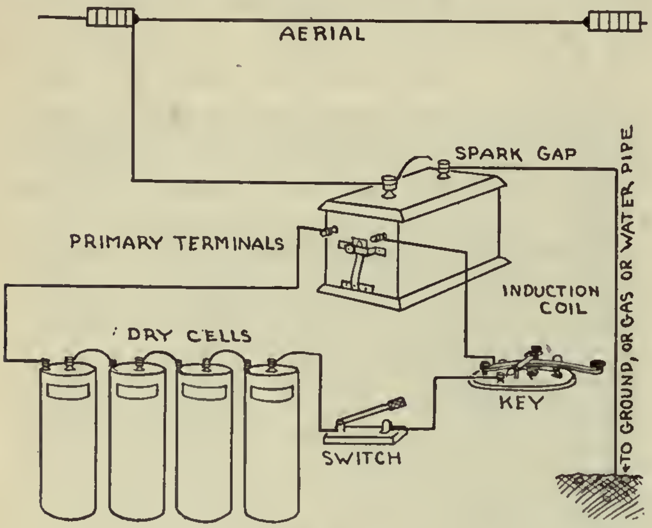


FIG. 455

The voltage in the ____ circuit is furnished by the dry cells. To make the electric current jump the spark gap a ____ voltage is necessary. The coil makes this ____ from the ____ voltage of the dry cells in the primary circuit. The key ____ and ____ the primary circuit. A dot is made by ____ while a dash is made by ____. One side of the ____ circuit is connected to the ____ while the other is connected to the ground.

Experiment 169. How may wireless messages be received?

At the other end of the room from the sending set, or in some other part of the building, place another single wire aerial similar to the one used with the sending set. Lead a wire down from this to a table.

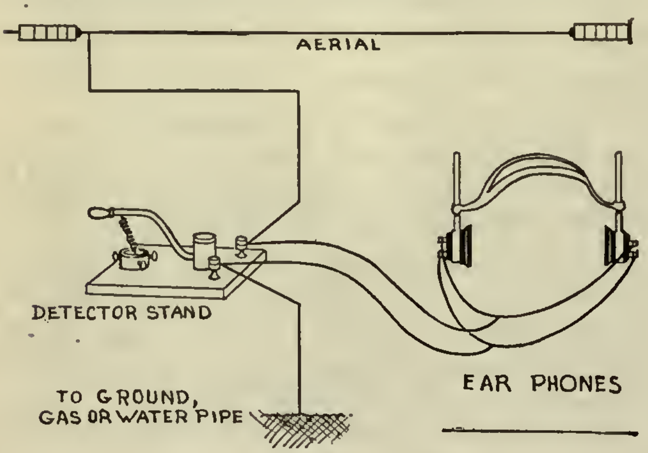


FIG. 456

A crystal may be secured at any radio store or one can be made from galena (lead sulphide). Connect one of the binding posts on the crystal to the aerial and the other to the ground. Connect the ear phones across the two binding posts of the crystal as shown in Figure 456.

Have some one send dots and dashes with the sending set and adjust the "cat whisker" on the crystal until you find a sensitive spot where you can hear the sending.

Summarize your conclusions in a carefully written paragraph.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What common experiences have you had with waves? If you have been to the sea shore you are familiar with the regularity with which the waves roll in upon the beach. You have no doubt read of messages placed in bottles and carried along for thousands of miles by ocean currents. In an earlier unit you learned how sound is carried through air, water, and other substances by waves set up by some disturbance such as a bell, a whistle, or a vibrating string. Have you ever made a string telephone and noticed how the sound waves travel along the thread? In these sound devices the human ear is a receiving set while the spoken word, the bell, the whistle, or the vibrating string may be broadcasting. The sound is carried from the sending device to the receiver by waves which travel through air, water, string, or some other material substance.

The beacon fires and heliographs of the ancients were used to send messages. The human eye was the receiving set and the messages were carried with the tremendous speed of light, 186,264 miles per second. Just think, seven and one-half times around the earth in the "tick of a watch." Every source of light is a broadcasting station sending out messages which may be received by the eye. As we stand in front of a fireplace the fire sends out waves which are too long for the human eye to see, yet our sense of feeling becomes a receiving station and picks them up. These are known as infra-red waves. Have you ever been sunburned? Then you have picked up the waves sent out by the sun which are too short for the eye to see, but which will cause irritation to the skin. These are known as ultra-violet waves.

Sound waves are carried by any solid, liquid, or gas. Water waves are carried by water. It is impossible to have a wave motion unless there is some medium in which to wave. Because scientists have never been able fully to understand what medium transmits ultra-violet waves, visible light waves, and infra-red heat waves, they assumed one and called it the "ether." The ether is supposed to fill all of the space of the universe, even between the molecules of solids, liquids, and gases, and the space of a vacuum. In this ether,

light waves, ultra-violet waves, and infra-red waves are supposed to be carried. These waves together with wireless waves, radio waves, and some others have come to be known as ether waves.

In Unit V, Topic 2, you studied about the visible spectrum and how it could be produced from white sunlight by means of a prism. You will recall that the colors produced in the descending order of their wave lengths were red, orange, yellow, green, blue, indigo, and violet. As has been noted, this is only a small portion of the entire ether spectrum. There are wave lengths longer than the red and shorter than the violet waves that are not detected by the human eye.

Light waves and wireless waves are similar. About the time of our Civil War there lived in Edinburgh, Scotland, a young mathematician, J. Clerk Maxwell. By applying his great knowledge of mathematics he was able to prove that light waves and other ether waves are similar. He thought that it should be possible to set up these other ether waves just as light waves can be created and controlled by man.

Many scientists began working on this problem, but it was not until 1888 that a young German scientist, Heinrich Hertz, made and detected waves of this kind. While working in his laboratory with a spark coil similar to the one which was used in Experiment 168, he was able to send out wireless waves. He attached a metal plate to each of the secondary terminals of his coil as shown in Figure 457. When the current was turned on in the coil and a spark jumped across the gap, these plates formed the aerial of his simple broadcasting set. Hertz discovered that when a loop of wire of certain length was placed near the spark coil in which current was flowing, a spark would jump between the ends of the loop. The coil was the first wireless sending set and the loop of wire the first receiving set.

How are wireless waves set up and messages sent? In making sound waves and light waves there must be some sort of disturbance such as a ringing bell or a source of light. To set up water waves in a still pond something must disturb the water. So it is with the making of wireless waves; there must be a disturbance to create them. Surging electrons in an electric spark between two pieces of metal will cause wireless waves to start up in the ether. The spark plugs of every automobile are little broadcasting stations, and the wireless waves which are sent out by the surging electrons can be picked up by some receiving sets. Sparks are frequently seen when electrons surge between the trolley wheel of the street car and the trolley wire. This also sends out a wireless wave into the ether. In fact, wherever an electric spark, caused by moving electrons, occurs, wireless waves are set up and radiate into the ether in every direction from the source.

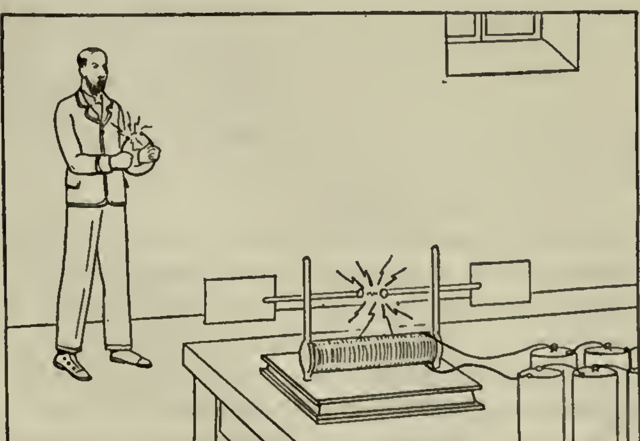
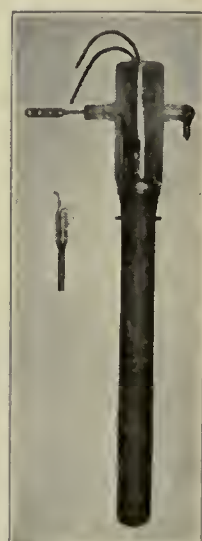


FIG. 457. HERTZ'S EXPERIMENT

To have sufficient energy to flow across a spark gap the electrons must have a very high pressure or voltage behind them. Dry cells and storage batteries might be used, but many of them would be required to produce this high voltage. A spark coil similar to the one which you used in Experiment 168 is a part of every automobile and is simply a device to raise the pressure or voltage back of the electrons so that they can flow across the gap in the spark plug and explode the gasoline. Low voltage battery currents are changed into high voltage currents by the spark coil. This enables the electrons to flow across a spark gap and become the center of disturbance in the ether, producing wireless waves. If a telegraph key is placed in the circuit of the spark coil with the batteries, long and short surges may be made with it. These will then be sent out as wireless waves in the ether, each wave series representing a dot or a dash, and thus messages may be sent. If one side of the spark gap is connected to an aerial and the other side to a water pipe, the wireless waves will be given a better start on their journey through the ether.



General Electric

FIG. 458. VACUUM TUBE USED IN BROADCASTING

Spark transmitters, which were used for many years to send wireless messages, have now been replaced because of better ways which have been discovered to make electrons surge back and forth. Dr. Alexanderson, an American, has discovered how an alternating-current electric generator may be used to move electrons back and forth rapidly and thus create ether waves.

Vacuum tubes may also be used to control electrons and cause them to set up ether waves. Figure 458 shows a vacuum tube of the type

used to produce electrical disturbances in the ether. When electrons surge back and forth in a wireless circuit, they are said to *oscillate.*

What are wireless waves? Our study thus far has shown that ether waves may be set up by causing electrons to surge back and forth. This may be accomplished by a spark coil, an electric generator, or a vacuum tube. The waves which are set up as a result of surging electrons are like light waves, heat waves, and ultra-violet waves which cause sunburn. All of these waves travel through the ether at the tremendous speed of 186,264 miles per second. This is about seven and a half times around the earth in one second. Also wireless waves are different from light waves, heat waves, and ultra-violet waves. To understand how they are different you must learn a little more about waves.

The distance from the top or crest of one wave to the top of the next one is called a *wave length.* You will recall from your study of sound, in the unit on air, that musical tones are varied in pitch by varying the rate of vibration or frequency of the sounding body and also that while sound waves may all travel at the same rate they may differ in wave length and frequency. Tones of high pitch or frequency have short wave lengths and tones of low frequency correspondingly longer wave lengths.

These principles all apply to a knowledge of light waves, heat waves, ultra-violet waves, wireless and radio waves. While all of these waves travel at the same speed as light, they are all different in wave length and frequency of vibration. Ultra-violet light has a wave length too short to be seen by the human eye, while heat waves, wireless waves, and radio waves are too long to be seen by the eye. The ultra-violet waves have a short length but a high vibration frequency, while the longer radio waves have lower vibration frequencies.

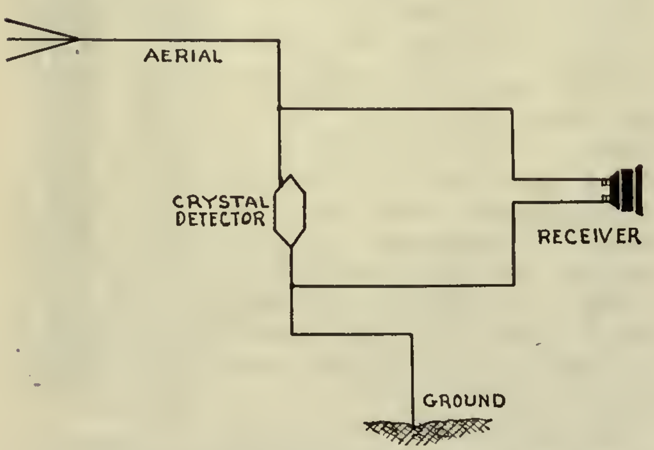


FIG. 459. DIAGRAM OF A CRYSTAL RECEIVING SET

How are electric waves and messages received without wires? About the time that Hertz was experimenting in Germany with the production of electric waves, Professor Branly, a Frenchman, discovered how these same waves might be used to ring a bell in another room. He made the discovery while experimenting with metal particles in a glass tube, trying to get electricity through them. A spark coil near by was started, and to Branly's surprise the metal particles were affected in such a way that current flowed through them. By placing a tube of metal particles in an electric bell circuit with batteries and starting a spark coil in another room, he could ring the bell.

Marconi, an Italian inventor, made improvements on the Branly "coherer," as it was called, and used it in his experiments first in England and later, in 1901, when wireless messages were first sent across the Atlantic Ocean.

The coherer as a device to detect wireless and radio waves was displaced when it was discovered that certain crystals such as galena, a crystal made up of lead and sulphur, could be used. We shall study how such a crystal detects the wireless wave. Figure 459 shows how the crystal is connected to the aerial, ear phones, and ground to make a simple receiving set.

The surging electrons in the secondary circuit of the spark coil send ether waves out into space from the aerial. These waves are vibrating very rapidly, or as we have learned to say, have a high frequency, much too high to be heard by the human ear or to be seen by the eye.

As these waves encounter a receiving aerial they set the electrons surging in its wires just as they surged in the sending aerial, first in one direction and then in the other.

The crystal detector acts as an electron valve. When the electrons go in one direction they can get through the crystal, but when they are moving in the opposite direction they cannot get through to the ground; hence they must go around through the ear phones and into the ground. Study Figure 460.

The electrons that must go through the ear phones to get to the ground form a current in the telephone electromagnets and cause the little iron disk to vibrate, sounding the dots and dashes which were sent out at the sending station.

While the crystal detector is still used for receiving wireless waves, it has been largely displaced by the vacuum tube. By use of the vacuum tube not only are electron surges detected, but they may be amplified hundreds of times. The next topic on radio will tell more about this invention and how it works.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today,* Unit 9

Clement, Collister, and Thurston, *Our Surroundings,* Chap. 17 (part)

Hunter and Whitman, *Science in Our World of Progress,* Unit 10

Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 25

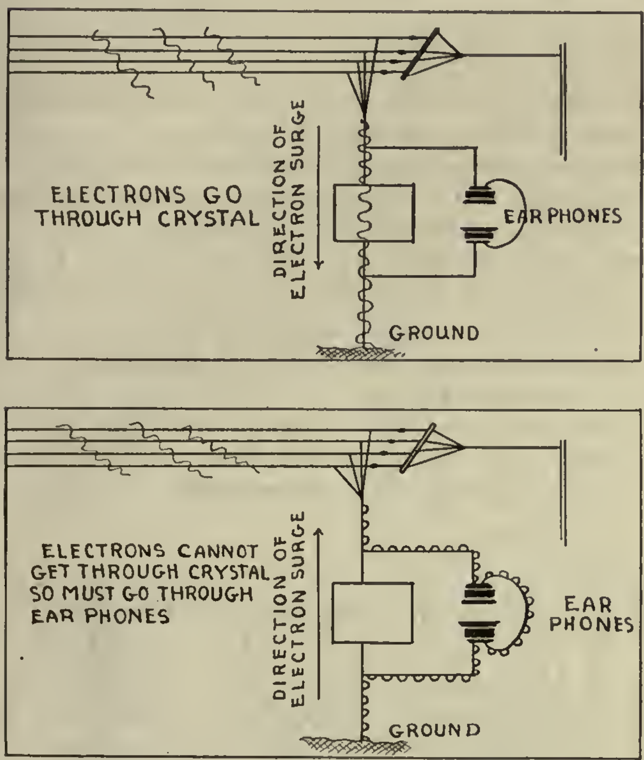


FIG. 460. HOW THE CRYSTAL WORKS

Pieper and Beauchamp, *Everyday Problems in Science,* Unit 16

Powers, Neuner, and Bruner, *Man's Control of His Environment,* Chap. 23

Skilling, *Tours through the World of Science,* Tours 11 and 12

Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 18

Webb and Beauchamp, *Science by Observation and Experiment,* Unit 2

Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 12

Special references

Meister, *Magnetism and Electricity*

Morgan, *The Boy Electrician*

Seaver, *The American Boy's Book of Electricity*

Mills, *The Letters of a Radio-Engineer to His Son*

Kendall and Koehler, *Radio Simplified*

Schubert, *The Electric Word*

Darrow, *Masters of Science and Invention*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of what wireless waves are.
2. An understanding of how wireless messages are sent and received.
3. Something of the history of wireless.
4. An attitude toward the importance of wireless as an agency of communication and international understanding.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions and comply with the instructions.

1. ____ discovered electric waves.
2. ____ first experimented with wireless.
3. Wireless waves are carried from the sending aerial to the receiving aerial by ____.
4. The frequency of an ether wave is its rate of ____.

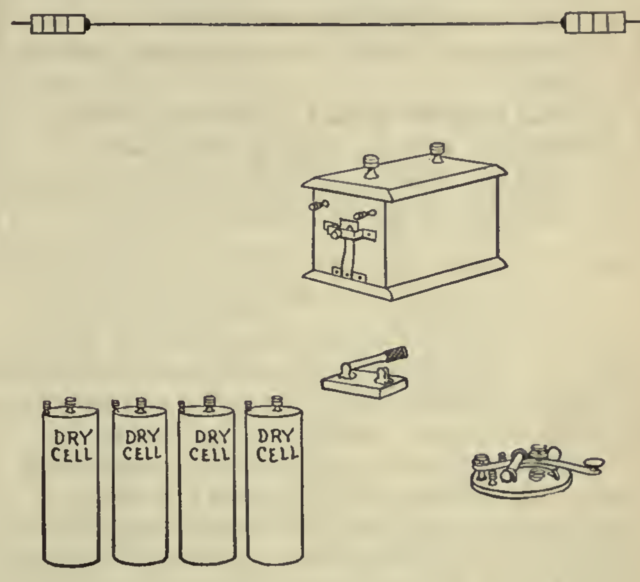


FIG. 461

5. The wave length of a wireless wave is the distance from ____ to ____.
6. In your notebook connect by a pencil line the parts of a simple wireless sending set as shown in Figure 461. The pencil line represents the wire.
7. What does the spark coil do?
8. What parts are included in the primary circuit of the spark coil?
9. What parts are included in the secondary circuit of the spark coil?
10. The voltage in the ____ is greater than that in the ____ circuit.
11. An ____ current wave is sent out by the sending set.
12. Explain what principle is used when a current is set

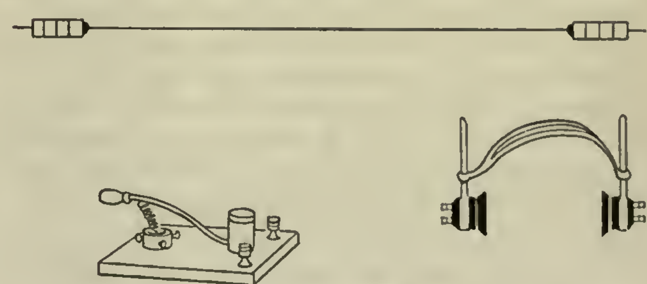


FIG. 462

up in the receiving aerial by the ether waves from the sending station.

13. The current in the receiving aerial is an ____ current.
14. What type of current is used in a telephone receiver?
15. The function of the crystal is ____.
16. In your notebook connect by pencil line the parts of a simple wireless receiving set like the one in Figure 462.
17. The colors of the visible spectrum in the descending order of their wave lengths are ____.
18. When electrons surge back and forth rapidly in a wireless circuit they are said to be ____.
19. Sound waves are detected by the ____; light waves, by the ____; and wireless waves, by means of a ____ which permits ____ to flow through it in one direction.
20. An example of ether waves shorter than those of the visible spectrum is ____.
21. An example of ether waves longer than those of the visible spectrum is ____.

TOPIC 5. COMMUNICATION BY RADIO

SUGGESTED PROBLEMS AND QUESTIONS

1. **How are wireless and radio alike?**
2. **What is a vacuum tube and how does it work?**
3. **What happens at the broadcasting station?**
4. **How does a radio receiving set work?**
5. **What are some of the recent advances in the application of the principles of the radio?**

SUGGESTIONS AND HELPS FOR STUDY

1. Secure a used vacuum tube which can be taken apart for study. If you are careful, the glass bulb can be filed around the brass base collar and easily removed, showing the inside of the tube clearly.

2. If you live near a broadcasting station, make a visit to it and study the equipment carefully.

3. Study the inside of a radio set either at home or at school to learn the number of tubes used, the number and type of transformers, the type of coils, and the number and type of condensers.

4. In the study of this topic you are likely to run into ideas and readings which you will not clearly understand. Do not be discouraged, for the science of radio has many difficult things in it. The explanation of tuning a radio set by condensers and coils involves a great deal of physics which will be difficult for you until you have studied more about electricity.

5. The following new words and phrases may be found in this exercise:

"A" battery—a low voltage battery used to supply energy to the filament of the vacuum tube.

"B" battery—a high voltage battery which keeps the plate of the vacuum tube charged positively.

antenna—the wires which are put out, usually at some height, to receive or send radio messages.

audion—a special name applied to the vacuum tube.

condenser—a device used in tuning a radio circuit; it is made up of successive layers of metal plates separated by layers of air or some other insulating material.

filament—the fine wire in a vacuum tube which glows red when supplied with electric current.

grid—the fine spiral of wire which surrounds the filament in the vacuum tube.

frequency—the number of vibrations per second.

kilocycle—a unit for measuring the frequency of radio waves. One kilocycle equals 1,000 cycles.

voice wave—the varying electric current set up in the transmitter or microphone circuit as a result of the sound waves' entering the microphone; the type of electrical current which goes over the wire in telephone communication.

carrier wave—the high frequency, alternating current wave, which carries the voice wave from the broadcasting station to the receiving aerial.

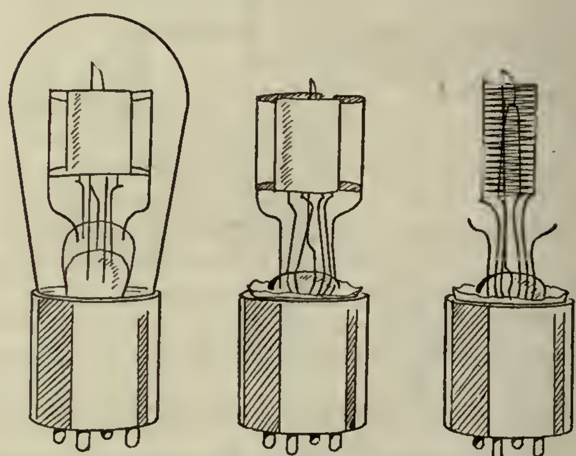


FIG. 463

modulated wave—the carrier wave upon which the voice wave has been impressed at the broadcasting station.

audio-frequency—vibrations which can be heard by the human ear.

radio-frequency—vibrations which are above the range of the human ear, usually more than 100,000 cycles per second.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 170. How is the vacuum tube constructed?

Carefully remove the glass bulb from an old vacuum tube by filing around it next to the brass base with a sharp tri-

[1] See workbook, p. 101.

angle file. Study the construction carefully. If no tube is available study Figure 463. Let these questions guide your observations. How many connections are made through the base of the tube? Can you locate a fine wire running from the glass base up the center of the tube and back? This is the filament. The coil of fine wire surrounding the filament is the grid. The solid metal plate around the grid is the plate. Do any of these touch each other? When your file first punctured the tube what did you observe? Why is this called a vacuum tube?

NOTE: Some reference reading on the construction and operation of both radio broadcasting and receiving sets should be done before performing the next experiment.

Experiment 171. What principle is used to tune a receiving set to the wave of a broadcasting station?

Stretch a wire between two supports as shown in Figure 464. From the wire suspend two pendulums, each having a length of about three feet, and two others about twenty inches in length. Arrange them alternately as shown in the diagram. One of the long pendulums represents a broadcasting station sending out a certain long wave length. The other long pendulum represents a receiving set tuned to this wave length.

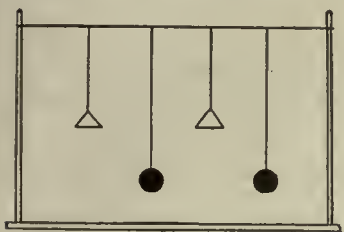


FIG. 464

In the same manner one of the short pendulums represents another broadcasting station tuned to a shorter wave length and the other short one, a receiving set tuned to receive the shorter wave length.

Start one of the long pendulums swinging and observe the result. Stop the long pendulum swinging and start one of the shorter ones swinging. Repeat this several times and see if you can discover how it illustrates the principle of tuning a radio set to the wave length of a certain broadcasting station.

In your notebook record your notes and complete the following statements.

When the long pendulum is started swinging its motion is carried by the ____ to the pendulum which has the same ____ and starts it ____. The shorter ones are not ____ by this. When the long pendulums are stopped and one of the short pendulums is started swinging, the other short pendulum ____, but the long ones this time are ____. This experiment shows that at any one time a receiving set may be tuned to only ____ broadcasting wave length. In this experiment the longer receiving pendulum could have been tuned to the shorter broadcastng wave by ____ it.

OTHER INVESTIGATIONS WHICH YOU CAN MAKE

1. Visit a broadcasting station.
2. Build a simple crystal radio receiving set.
3. Build a simple tube radio receiving set. (See Caldwell, Eikenberry, and Glenn, *Laboratory Experiments in General Science.*)

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How are radio and wireless alike? In the recent study of wireless you learned how messages might be sent in code without wires. This was made possible by setting up electrical disturbances with surging electrons and then, with a coherer or a crystal, detecting the waves.

Radio is different from wireless in the same way that the telephone is different from the telegraph. In the telegraph, messages are sent in code, while in the telephone the conversation and sounds may be changed into electric currents and carried over the wires.

In radio, sounds are changed into electrical waves and broadcast without wires. While it is not practicable to use a spark coil to send out radio waves, the simple crystal receiving set used to pick up the wireless waves may also be used to pick up radio programs. This is the experience of many who have built crystal receivers. Figure 459 shows a drawing of a simple crystal receiving set which may be used to hear radio broadcasts.

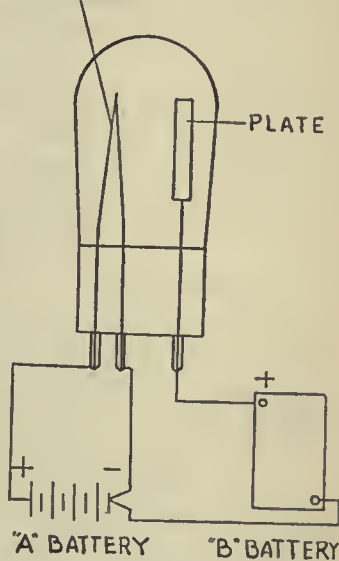


FIG. 465. THE FLEMING VALVE

The development of the vacuum tube made radio possible. A few years after the invention of the electric lamp Edison discovered that electricity could be made to flow in only one direction through the space around the hot filament of his bulb. This is known as the Edison effect. It was put to work by Fleming, an English scientist, who added a plate to the inside of the electric bulb as shown in Figure 465. This is known as the Fleming valve. When the filament was heated with current from an "A" battery and a "B" battery connected in such a way that the plate was always kept positive (see Fig. 465), the valve could be used to detect wireless waves. This proved to be much more sensitive than either the coherer or crystal for receiving wireless waves.

A few years later Dr. Lee DeForest further improved the Fleming valve by placing a third element, called the grid, between the filament and plate as shown in Figure 466. This is the modern vacuum tube used so extensively in communication.

Not only have vacuum tubes improved the reception of wireless and radio waves, but they have made radio broadcasting possible. Figure 458 shows a modern vacuum tube used in broadcasting stations.

What is a vacuum tube and how does it work?

From Experiment 170 you have learned that the modern vacuum tube has three essential elements. These are the filament, the grid, and the plate. Figure 463 shows a vacuum tube with the glass bulb removed in one case, and the plate removed in another. The four prongs at the bottom are the connections. Two of them connect with the filament, one with the grid, and one with the plate.

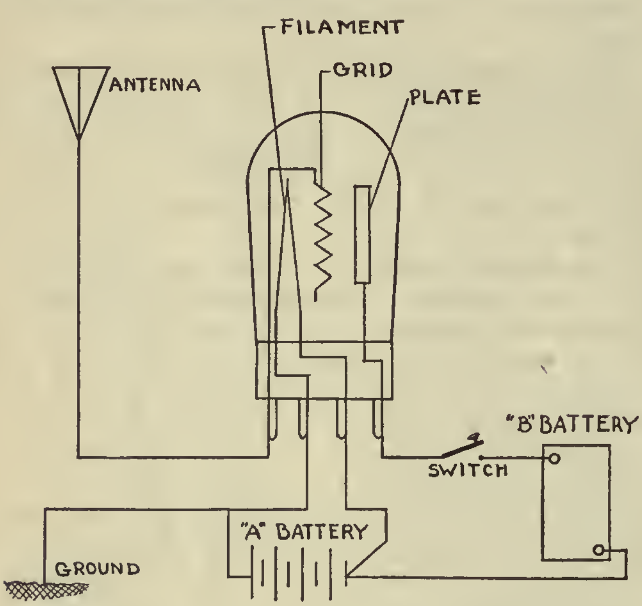


FIG. 466. DE FOREST'S IMPROVEMENT OF THE FLEMING VALVE

Among the various uses of vacuum tubes at the broadcasting station we shall consider only two. The tube may be used to set up electrical disturbances, or oscillations, just as the spark coil was used in the simple wireless set. It is better than the spark coil for this purpose because the surging electrons may be more carefully controlled in the tube. Another use to which the vacuum tube is put in both broadcasting and receiving sets is to build up or amplify electrical waves which are weak. Thus by use of amplifying tubes the normal voice of a speaker may be made thousands of times stronger. Tubes are used for this purpose in modern public address systems so commonly used in large auditoriums and in outdoor amphitheatres.

Courtesy Radio Station KMOX

FIG. 467. INTERIOR VIEW OF BROADCASTING STATION

What happens at the broadcasting station? Figure 467 shows an interior view of a broadcasting studio. This picture gives little evidence of the complex electrical circuits, tubes, and generators which are "behind the scenes" but which are necessary before the sound made by the instruments or voices of the performers can be changed to ether waves and sent out. Figure 468 shows some of the equipment in a modern broadcasting station.

Recall from your study of wireless that ether waves can be set up by the surging electrons of an electric spark. Similar ether waves can be set up by electrons surging in a vacuum tube. Tubes have largely replaced spark coils for wireless sending.

Courtesy Radio Station KMOX

FIG. 468. EQUIPMENT USED IN BROADCASTING STATION

Ether waves such as those which are set up by the surging electrons in a spark coil are vibrating many thousand times a second and are too rapid to be heard by the human ear. We speak of them as *radio-frequency waves.* Each spark sends out a little train of waves which soon die out. These are spoken of a *damped waves,* and each series will give an impulse to the telephone receiver. The length of these little wave series is con-

trolled by the sending key. A long series is a dash and a short series is a dot. When electrons are made to surge in a vacuum tube a high frequency radio wave is sent out. This is an undamped or continuous wave which cannot be heard by ear and will not operate the telephone receivers. Figure 469*a* shows an undamped or continuous wave of very high frequency sent out by a vacuum tube.

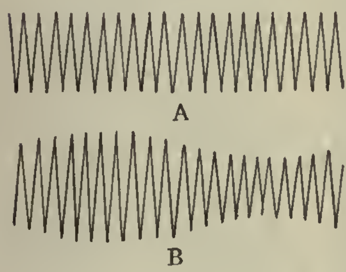


FIG. 469. UNDAMPED WAVE AND MODULATED WAVE

The undamped or carrier wave, as it is sometimes called, must be changed before starting its journey from the broadcasting antenna. It must have the voice wave placed upon it. This is accomplished by placing a sensitive telephone transmitter, called a *microphone,* in the plate circuit and speaking, singing, or playing into it. From your study of the telephone, recall that as sound waves affect the transmitter they are changed into electric currents which pass through the wire. Voice waves are sent into the plate circuit of a vacuum tube at the broadcasting station. At the same time electrons are surging in the tube, producing a carrier wave as shown at *a*. The voice wave is placed upon the carrier wave in such a way as to produce a combination or *modulated* wave as shown at *b*. This modulated wave is sent out from the antenna of the broadcasting station. The voice wave of the microphone may be produced by any sort of sound disturbance in the studio and will modulate the carrier wave in such a way that the same sound will be reproduced in the loud speakers of receiving sets.

Exercise. *Write a summary statement showing clearly each step involved in changing a sound wave into a modulated ether wave that is sent out by a broadcasting station.*

How does a radio receiving set work? From your study of the crystal wireless receiver, recall that the crystal was used to change the alternating-current ether wave into a direct-current wave which would operate the telephone receivers. When the vacuum tube is used to detect either wireless or radio waves its action is quite similar, that is, it changes the alternating-current, high frequency waves into a direct-current wave which will operate the ear phones or loud speaker. Let us study how this is accomplished by the tube.

Figure 466 shows a vacuum tube connected into a circuit. Notice that the antenna is connected to the grid; that the "A" battery supplies current to light the filament of the tube, and that the "B" battery has its positive pole connected to the plate. This keeps the plate always positive.

As current flows through the filament of the tube electrons are thrown out into the space around it. This is what caused the effect noticed by and named for Edison. You will recall from previous experiments that electrons are negative particles of electricity. The plate is always positively charged by being connected with the positive side of the "B" battery. Being positively charged means that there is a shortage of electrons on the plate, and therefore many of the electrons thrown out by the hot filament will rush across to the plate and then on to the "B" battery. A stream of electrons is *an electric current,* and if a delicate ammeter is placed in the plate circuit it will show that a current is flowing.

By reference to Figure 466 you will see that the grid is connected with the antenna. Let us see what effect the grid will have upon the flow of electrons from the filament to the plate. Do not forget that the grid is located directly between the filament and the plate.

As the ether waves from the broadcasting station cut across the antenna wires, weak alternating currents of very high frequency are set up and carried to the grid. From your study of electricity you know that an alternating current flows first in one direction and then in the other. First it is positive and then negative. As such a current flows through the grid it charges the grid positively for a brief fraction of a second, then negatively, and then repeats. When the grid is positive it will help the plate as electrons from the filament are attracted to it. When the grid is negative it will repel the electrons from the filament, and no current will flow. In the next instant the grid charge will change to positive and electrons will flow to the plate

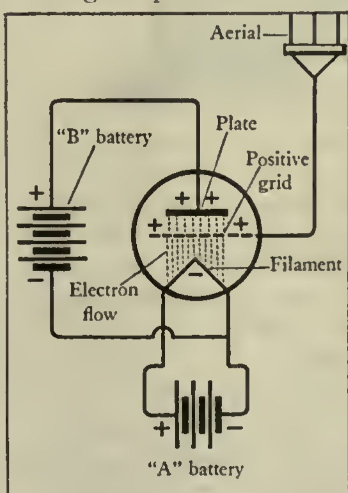


FIG. 470. VACUUM TUBE SHOWING GRID POSITIVE AND ELECTRON STREAM FLOWING THROUGH PLATE

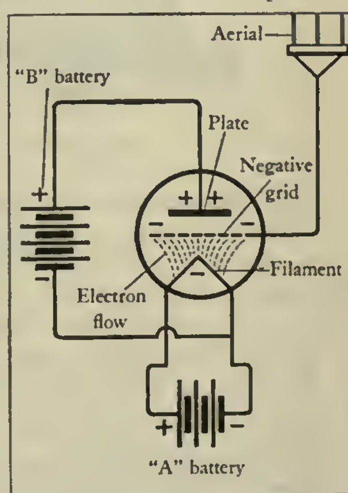


FIG. 471. VACUUM TUBE SHOWING GRID NEGATIVE AND NO ELECTRON STREAM FLOWING

again. Thus the grid is a valve which allows electrons to flow from filament to plate one instant and prevents them from flowing the next. That is, it changes the alternating currents in the grid circuit to direct currents in the plate circuit. Ear phones or a loud speaker are in the plate circuit where they are operated by the direct current resulting from the rectifying action of the vacuum tube. The currents set up in the antenna by the broadcast waves are very weak and could hardly be used to operate ear phones. Before it is possible for these small currents to operate a loud speaker or ear phones, they must be amplified. This is accomplished in the receiving set either by a series of vacuum tubes or by transformers. In most sets both tubes and transformers are used.

Radio receiving sets may be tuned to different frequencies. Many of you have tuned radio receiving sets to different stations and have wondered how this is accomplished. Recall from Experiment 171 that a swinging pendulum could start another of the same

FIG. 472. RADIO RECEIVING SET

length swinging but would not affect pendulums of different lengths hung from the same wire. The vibrations set up by the swinging pendulum were carried along the wire to the other one of the same length. The two pendulums were tuned to the same frequency. One represented a broadcasting station and the other of the same length a receiving set. The pendulums which were longer or shorter could have been tuned to the frequency of the swinging pendulum by making them the same length.

Tuning a radio set is accomplished through a little different method. Each broadcasting station has a set frequency, that is, a definite number of vibrations per second for its carrier wave. This frequency is set by the Federal Radio Commission and must be strictly adhered to. Suppose a station is broadcasting on a frequency of 550 kilocycles. "Kilo" means thousand. Therefore the carrier wave of this station would be making 550,000 vibrations per second. If you wish to get the program of this station on a receiving set, you

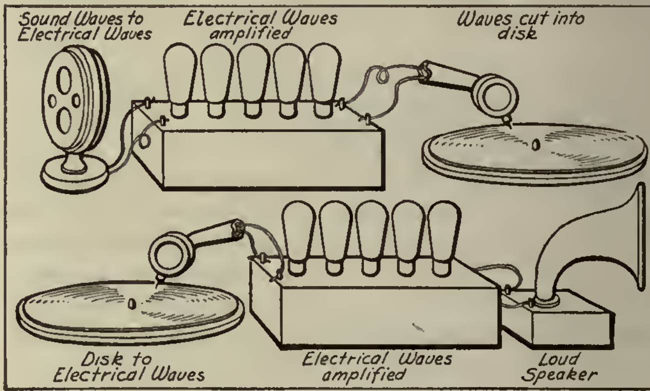


FIG. 473. SCHEMATIC OF RECORDED SOUND WAVE ON RECORD

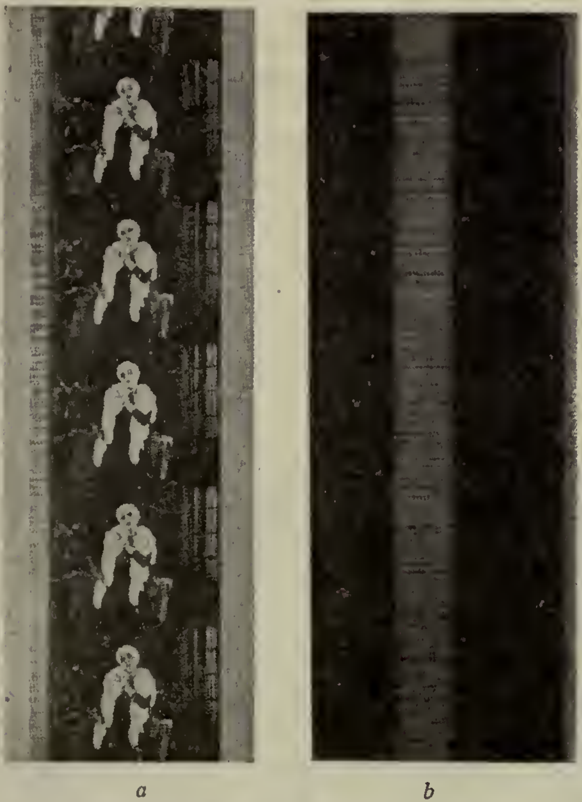
must "tune" the set until it will respond to this frequency just as one pendulum responded to the vibration sent along the wire by the one of the same length while vibrating. Tuning is accomplished by turning the dials of the set. This turns coils or variable condensers or both in the circuit until it is in tune with the broadcast wave desired.

What are some of the recent advances in the application of the principles of radio? Not only has the radio added greatly to home entertainment, but it has become very important as an agency of communication. Trans-oceanic telephony is made possible by radio. Communication from airplanes and the radio compass could hardly be dispensed with. Short wave broadcasting is used by many city police departments to communicate with roving police cars which are thus enabled more quickly to apprehend criminals. Radio made possible the daily communication with Admiral Byrd when he was thousands of miles away in the frozen Antarctic continent.

The past few years have seen not only the remarkable developments of the radio but also sound motion pictures, sending pictures by wire, and television or sending scenes. It is possible that television may soon be perfected to the point where radio sets will be equipped to receive scenes sent without wires.

There are two methods of recording sound for motion pictures, one in which the sound waves are placed upon a record as for the phonograph and the other in which the sound wave is placed on the same film as the picture. Sound placed upon a record is reproduced in much the same manner as a phonograph

reproduces sound except that the sound waves are first changed to electric waves and after having been amplified are made to operate a loud speaker. Study



Courtesy Bell Telephone Laboratories

FIG. 474. SOUND FILMS
A. SOUND RECORD ON MARGIN OF PICTURE
B. SEPARATE SOUND FILM

Figure 473 and learn how this is accomplished. Figure 474 shows a strip of motion picture film with the sound wave photographed beside the picture.

Courtesy Bell Telephone Laboratories

FIG. 475. PHOTO-ELECTRIC CELL

In reproducing sound which has been placed on the film a modern device called the *photo-electric cell* is used. This device changes light energy into electrical waves. Figure 475 shows a photo-electric cell. Figure 476 shows, above, how sound is recorded on a film and, below, how it is reproduced from the film. Study the diagram carefully and see if you can explain each of these processes clearly.

Sending pictures and other documents by wire has been advanced to the point where many of the larger cities of the country are now interconnected to furnish this service and many news pictures are sent in this way.

The sending mechanism consists of a cylinder moved by a driven screw. A transparent photograph positive is placed on the cylinder, which is then moved slowly past a very narrow beam of light. Inside the cylinder is a photo-electric cell connected to the re-

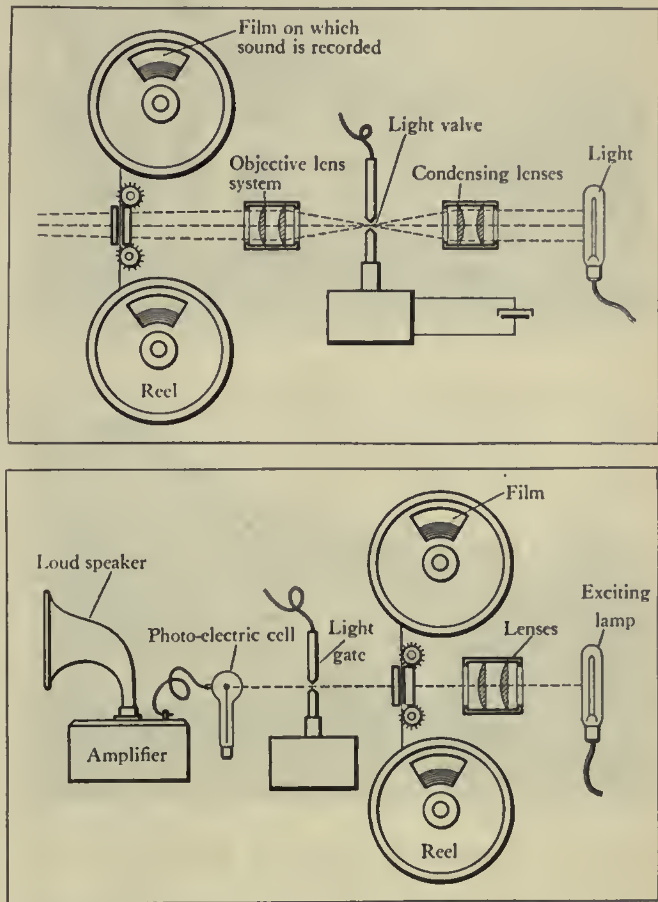


FIG. 476. HOW SOUND RECORDED ON FILM IS REPRODUCED

ceiving device in a distant city. As the light beam shines through the transparent picture, the lights and shadows recorded on the film are changed to electric waves by the photo-electric cell. After being amplified these electric waves are sent to the receiving device

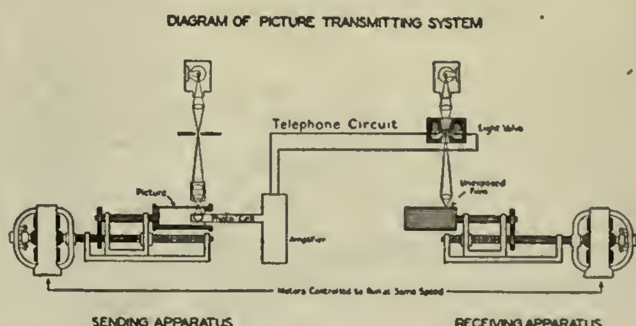


FIG. 477. TELEPHOTOGRAPHIC SENDING AND RECEIVING EQUIPMENT

in the distant city. Figure 477 is a diagram of a telephoto sending and receiving device.

The electric waves sent out from the sending set are changed back into light waves at the receiving sta-

Courtesy Bell Telephone Laboratories

FIG. 478. ORIGINAL PHOTOGRAPH (ABOVE) AND TELEPHOTOGRAPHIC REPRODUCTION (BELOW)

tion by making them control a light valve. The light valve controls a small beam of light from a lamp, permitting varying amounts of light to shine through it on to an unexposed negative. The negative is also fastened to a cylinder which is pushed past the light

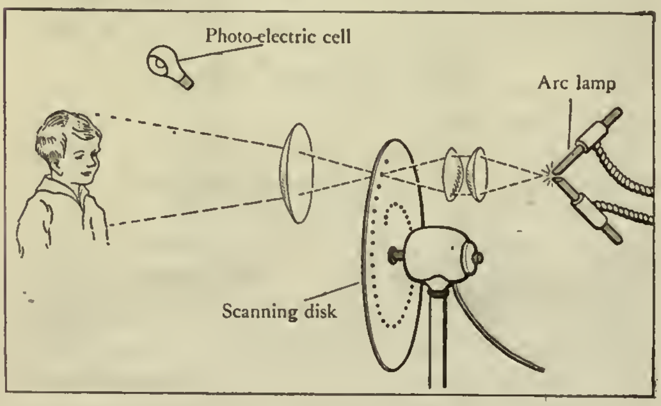


FIG. 479. HOW SCENES ARE SENT BY WIRELESS

beam by a motor-driven screw. The motor at the sending station is driven at exactly the same speed as the one at the receiving station. This is precisely controlled by a special circuit.

Exercise. *Study Figure 477 and see if you can trace the process through the sending set and through the receiving set.*

It is possible to send pictures by wireless, in which case about the same type of equipment is used. The electric waves from the photo-electric cell are then sent by wireless instead of by telephone.

It is possible that within the next few years television will be perfected to the point where many radio sets will be equipped to receive scenes. At present there are several independent stations broadcasting regular television programs, and it is estimated that

Courtesy Bell Telephone Laboratories

FIG. 480. TELEVISION SENDING DEVICE

there are more than fifteen thousand television receivers in the United States. Recently one of the large chain broadcasting companies began experimentation with television. It is indeed almost unbelievable that in the near future we may sit in our homes and see a play enacted in a distant city. Television can be accomplished either over wires or by radio.

Figure 479 is a diagram of how scenes are sent by television, and Figure 480 is a picture of the equipment used in sending. Figure 481 shows the equipment used in the reception of television.

In the sending set a beam of light from an arc lamp is sent through the openings in a rapidly moving disk known as the scanning disk. The openings in the scanning disk are arranged in a spiral in such a way that the beam of light scans across the scenes to be sent and is then reflected to the photo-electric cell. The photo-electric cell transforms the light energy that strikes it into electric waves which vary just as the

lights and shadows in the scene vary in intensity. These electrical waves from the photo-electric cell are then amplified and sent out either by wire or wireless.

At the receiving end the electrical waves are very weak and so must be amplified again by means of vacuum tubes.

After amplification the waves are sent to a neon glow tube. This tube flashes as the amplified waves are sent through it. The flashes vary just as the electrical pulses varied with the lights and shadows in the scene that was sent. When these flashes are viewed

Courtesy Bell Telephone Laboratories

FIG. 481. TELEVISION RECEIVING DEVICE

through a scanning disk, which is like the one in the sending set and which is turning at the same speed, the scene that was sent out is recreated for an observer looking into a small frame as shown in Figure 481.

Recently improved methods of scanning have been developed, one of which makes use of another type of tube known as a cathode ray tube.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Unit 9
Clement, Collister, and Thurston, *Our Surroundings*, Chap. 17 (part)
Hunter and Whitman, *Science in Our World of Progress*, Unit 10
Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 25
Pieper and Beauchamp, *Everyday Problems in Science*, Unit 16
Powers, Neuner, and Bruner, *Man's Control of His Environment*, Chap. 23
Skilling, *Tours through the World of Science*, Tours 11 and 12
Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 18
Watkins and Bedell, *General Science for Today*, Chap. 25
Webb and Beauchamp, *Science by Observation and Experiment*, Unit 2
Wood and Carpenter, *Our Environment: How We Use and Control It*, Topic 12

Special references

Lunt, *Everyday Electricity*
Meister, *Magnetism and Electricity*
Morgan, *The Boy Electrician*
Seaver, *The American Boy's Book of Electricity*
Mills, *The Letters of a Radio-Engineer to His Son*
Kendall and Koehler, *Radio Simplified*
Darrow, *Masters of Science and Invention*
American Telephone and Telegraph Co., *Through Electrical Eyes*
American Telephone and Telegraph Co., *Synchronized Reproduction of Sound and Scene*
American Telephone and Telegraph Co., *Two-way Television*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. A knowledge of the construction of the vacuum tube.
2. How the vacuum tube acts as a detector of radio waves.
3. How radio frequency waves are modulated by voice waves.
4. A knowledge of the meaning of tuning and something of how it is accomplished in a radio set.
5. A knowledge of the parts used in a radio receiving set.
6. A knowledge of what happens in a broadcasting set.
7. The concept of radio waves and how they are transmitted.
8. An understanding of some of the recent advances in communication.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The radio waves sent out by different broadcasting stations are alike in that they travel at the ___ but different in ___ and ___.
2. The high frequency radio wave is sometimes called the ___ wave.
3. In general ___ wave length transmission is used for sending long distances.
4. When the electric wave from the microphone is impressed on the high frequency wave, the latter is said to be a ___ wave.
5. The three essential parts of the vacuum tube are ___.
6. The principal use of the hot ___ is to furnish electrons.
7. The ___ is always positively charged.
8. The aerial currents come to the ___ of the vacuum tube.
9. A radio receiving set will pick up a given station only when it is ___ to that station's ___.
10. Vibrations which are above the limit of the human ear are often spoken of as ___.
11. When a vacuum tube acts as a detector it is essen-

tially serving to change the ____ waves into ____ current waves.

12. Make a diagram showing the parts of the three-element vacuum tube.

13. Explain in detail how the tube acts as a detector.

14. The ____ of the vacuum tube acts as a valve controlling the flow of electrons from the ____ to the ____.

15. The currents set up in the aerial of a receiving set are of very high ____.

16. These currents are amplified by ____ and by ____.

17. The loud speaker is essentially a ____.

18. Vibrations between ____ and ____ are called radio frequency because they are above the range of the ____.

19. The "A" battery is used to ____.

20. Vacuum tubes are used not only in radio communication but also in ____.

21. Some radio sets are called "5-tube sets." These generally have one tube for a detector, two for radio frequency amplification, and two for audio frequency amplification. Explain what is meant by the last two statements.

22. What does the rheostat in the filament circuit do?

23. ____ and ____ are used to tune radio sets.

24. Sound for moving pictures may be recorded either on a ____ or on ____.

25. A photo-electric cell changes ____ energy to ____ energy.

26. When scenes are sent by wire or wireless the process is called ____.

SUPPLEMENTARY MATERIALS

Reading suggestions

Hogan, *The Outline of Radio* (Little)
Collins, *The Radio Amateur's Hand Book* (Crowell)
Burns, *The Story of Great Inventions* (Harper)
Bond, *The American Boys' Engineering Book* (Lippincott)
Caldwell and Slosson, *Science Remaking the World* (Doubleday)
Elliot, *The Romance of Savage Life* (Lippincott)
Gibson, *The Romance of Modern Electricity* (Lippincott)
Holland, *Historic Inventions* (MacRae Smith)
Darrow, *Masters of Science and Invention* (Harcourt)
Iles, *Leading American Inventors* (Holt)
Marshall, *The Story of Human Progress* (Macmillan)
Johnson, *Modern Inventions* (Nelson)
Baker, *The Boy's Second Book of Inventions* (Doubleday)
Williams, *The Romance of Modern Invention* (Lippincott)
Yates, *ABC of Television* (Henley)
Woodbury, *Communication* (Dodd)

Reports which may be prepared

1. Communication by the heliograph
2. Laying an ocean cable
3. What happens at the telephone exchange
4. Early telephones
5. Modern devices in the telegraph office
6. The workings of the dial phone
7. Submarine signaling during the war
8. An electron goes through the radio set
9. Picture writing of the ancients
10. The making of a modern newspaper
11. Edison's contributions to telegraphy
12. The workings of the U. S. Mail
13. The screen grid radio tube
14. The future of television
15. The possibilities of sending pictures by wireless

Great scientists you should know about

1. Samuel F. B. Morse
2. Alexander Graham Bell
3. Guglielmo Marconi
4. Lee DeForest

Investigations and things to do

1. Build a telegraph key and sounder.
2. Build a telephone transmitter.
3. Build a telephone receiver.
4. Build a wireless sending set.
5. Build a crystal receiving set.
6. Build a tube radio set.

UNIT XIII. TRAVEL AND TRANSPORTATION

Our present mode of living has been made possible largely through the development of speedier and more reliable methods of travel and transportation. Did you ever stop to consider where many of the things come from which you use day after day? Think of the many sources of the food you eat. Your breakfast cereal may have been manufactured in the state of New York from wheat grown in Kansas. You eat oranges from California and Florida, nuts from South America, and dates from Egypt. Likewise consider the many different sources of the materials in your home. Where did the lumber come from? The stone and glass? The copper wire and electrical fixtures? The furniture? You see that many of the things we use, before they reach us, are transported hundreds or even thousands of miles. Many of the things we use today that are considered necessities of life were regarded as luxuries a hundred years ago.

The history of the developments in the fields of science and invention which have produced our modern means of travel by land, water, and air is a most interesting and fascinating field of study. The earliest English settlers in America had no way of travel except on foot. Today it is possible to travel from New York City to California, approximately 3,000 miles, in one day. Two months were required by Columbus to make his first trip across the Atlantic. Many of our modern ocean liners can make the trip in less than a week. Aviators have crossed the Atlantic Ocean in less than two days.

You are living in an age when great developments are taking place in the fields of travel and transportation. Land and water transportation are being developed to a high degree of efficiency and safety. The recent spectacular air flights by such aviators as Lindbergh, Byrd, Coste, and Amelia Earhart Putnam have caused us to focus our attention on the future possibilities of travel and transportation in the air. Successful commercial air lines are now in operation, and though this industry is still in its infancy, the future holds much promise.

In this unit you will have an opportunity to learn more about the developments taking place in travel and transportation. Also you should learn about the scientific principles upon which transportation is based.

How many of these questions about transportation can you answer? Answer as many of the questions as you can.

1. What methods of transportation are used in your community?
2. Have any street car lines been abandoned in your community? Why?
3. Can you drive an automobile? Do you know what the various parts of an automobile are and what each part is used for?
4. Why do some things float in water?
5. Why is it possible for steel ships to float?
6. What keeps a kite in the air?
7. What keeps a dirigible in the air?
8. What keeps an airplane in the air?
9. What is a monoplane? A biplane? A hydroplane?
10. How does an electric motor operate?

TOPIC 1. TRANSPORTATION ON LAND

SUGGESTED PROBLEMS AND QUESTIONS

1. **How have highways been improved since early times, and what are the causes for the change?**
2. **How do the various parts and systems of the modern automobile work together to make it run?**
   a) **The chassis**
   b) **The power plant**
   c) **The power-transmission system**
3. **How has transportation by rail been improved?**
4. **Of what importance is electricity in modern transportation?**

SUGGESTIONS AND HELPS FOR STUDY

1. Read carefully the problems listed above and be sure that you understand them before you begin their study and investigation.

2. In connection with problem 2, if you have an automobile at home, examine it and find the various parts and learn their functions.

3. The following words may be new and difficult for you. Study them carefully.

macadam—broken stone used for macadamizing roads.

dynamo—a machine for converting mechanical energy into electrical energy.

carburetor—a device on a gasoline engine by which air is mingled with gasoline vapor.

chassis—automobile frame.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 172. Does steam possess energy?

Put a small amount of water into a test tube. Push a greased cork stopper into the tube, not too tightly. Hold the test tube in a flame by means of a test tube holder. Keep the test tube pointed away from your body. Do not point it toward any other person. Observe what happens after the water begins to boil. Write your observations and answer the questions.

What change took place in the water as it boiled? What happened to the cork? Why does the steam have a push? How could this push of the steam be harnessed?

Activity 173. What are the parts of a steam engine and how does it operate?

A steam engine is a device that harnesses steam and changes the force of expanding steam into mechanical energy. Obtain a model of a steam locomotive like the one shown in Figure 482. If no model is available in your school, use the diagram of a steam engine and boiler (Figure 484). Study it carefully and explain in your own words how the engine works.

Experiment 174. Where does the power come from in a gas engine?

Find a tin coffee or syrup can (large size) with a good lid. Make a hole in the side of the can about one inch from the bottom. Attach a piece of rubber tubing to a gas jet and insert the end of the tube into the hole in the side of the can. Make a hole in the center of the lid. Turn on the

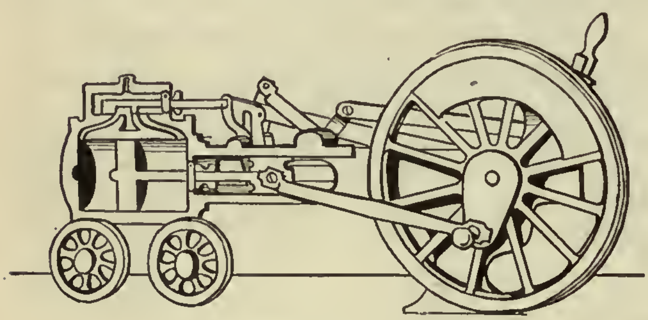


FIG. 482. MODEL OF STEAM LOCOMOTIVE

gas until it drives the air out of the can. Turn off the gas and hold a lighted match to the gas escaping through the hole in the lid. Stand back and wait. What happened? Did the exploding mixture of gas and air possess energy? What is the evidence for your answer?

(Teacher demonstration)

Pour half a teaspoonful of gasoline into a quart jar. Cover it. After several minutes remove the cover and hold a lighted match to the mouth of the bottle. Record your observations.

Experiment 175. What does the carburetor of the automobile do?

Examine an atomizer used either for a medicinal spray or a perfume spray. What does an atomizer do to a liquid? Discover how the atomizer makes this change in the liquid.

[1] See workbook, p. 104.

Examine an old automobile carburetor or study Figure 483. Take the carburetor apart, if possible, and see if you can discover how it is like the simple atomizer which you have studied above. These questions will guide your study.

Where does the liquid gasoline come into the carburetor?

What does the float valve do?

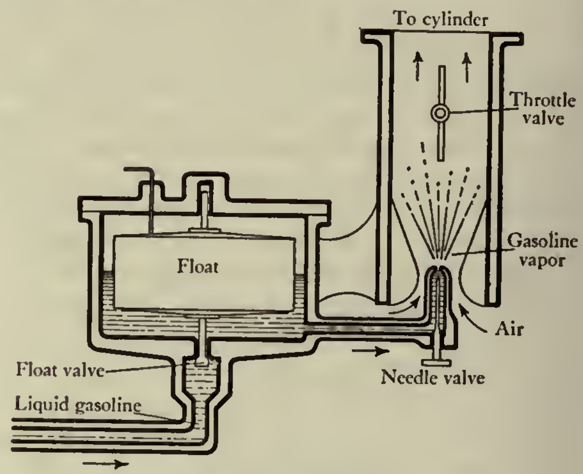


FIG. 483. CARBURETOR

Where does the gasoline go from the float chamber?

What does the needle valve do?

What is mixed with the gasoline vapor in the mixing chamber?

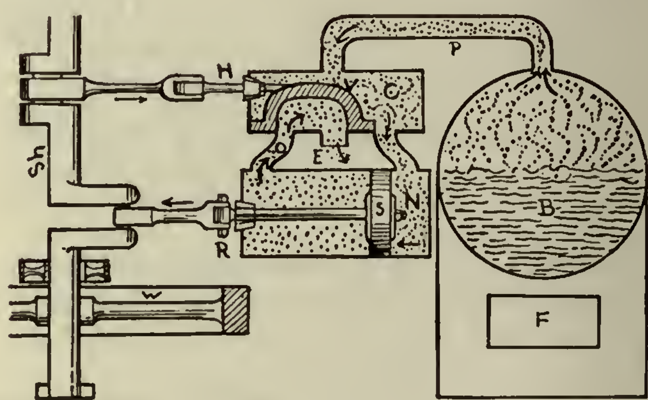


FIG. 484. STEAM BOILER AND ENGINE

How does this get into the carburetor?

Where is the choke valve and what does it do?

Where is the throttle valve and what does it do?

Record your notes and complete the following statements.

Atomizers and carburetors are used to change ____ to ____. In the carburetor ____ is mixed with ____ vapor to form the explosive mixture which goes to the cylinder. The ____ valve is on the air inlet. The ____ valve controls the ____ and ____ mixture going to the cylinder. Liquid gasoline is kept at a definite level in the ____ chamber by the ____ valve.

Experiment 176. How is the gas and air mixture exploded in the cylinder of an automobile engine?

Secure a can of about a gallon capacity, with a tight fitting lid. A smaller size will work. Make a hole in the side and insert an old spark plug taken from an automobile.

Secure a spark coil and connect it with three dry cells and a switch, as shown in the illustration. Attach the high tension or secondary wires, one to the spark plug and the other so that it touches some part of the can. (Be cautious in handling high voltage wires.) Now spray a little gasoline into the can with an atomizer or Flit spray. Place the lid on securely and close the switch. Stand away from the can and be cautious as the switch is closed.

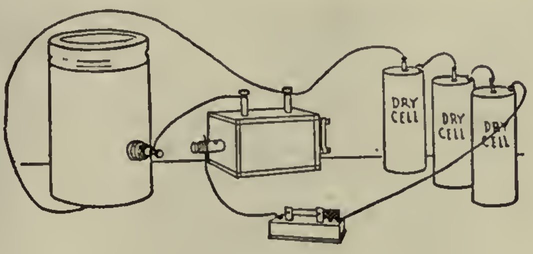


FIG. 485

Answer the following questions about the experiment. Is the voltage of the batteries low or high? Is the voltage required to make the current flow across the gap in the spark plug low or high? What does the spark coil do? Explain how the energy of the exploding gas might be harnessed.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

How have highways been improved since early times, and what are the causes for the change? Roads have long aided man in transportation. Among the most lasting of the monuments to the Roman Empire are the roads built to connect Rome with its provinces. Many of these roads, built from 1,500 to 2,000 years ago, are still in actual use or are being used as foundations for modern highways. Europe has long been noted for its fine roads and today has a greater proportion of its roads improved than North America.

In the United States road building was given little or no attention until the close of the Revolutionary War. Between 1790 and 1812 over three hundred permits for the construction of turnpikes were given to private companies. These turnpikes, built either of plank or gravel, comprised nearly 5,000 miles of road and an investment of more than six millions of dollars. Toll gates were placed about every ten miles on these to enable the owners to collect on their investment. The modern toll bridge is a remnant of this early custom. The turnpikes, while an improvement over the earlier trails, were very rough and difficult to keep up. One of these early roads, the Lancaster Turnpike, was built between Philadelphia and Lancaster, Pennsylvania, a distance of sixty-two miles. Other roads of this period which became famous are the Mohawk Trail, built from Albany to Buffalo; the Pennsylvania State Road built from Philadelphia to Pittsburgh; the Oregon Trail from Independence, Missouri, to the Columbia River in Oregon, a distance of two thousand miles; the Santa Fe Trail from Independence to Santa Fe, New Mexico; the National Trail, built by the government in 1830 from Hagerstown, Maryland, to the Pacific Coast.

The development of the automobile has brought our modern roads. The rapid rise of the automobile and bus as means of transportation has created a demand for wider and smoother roads. Many improved roads were formerly made of water-bound macadam. This type of road was named for John McAdam, a Scotch engineer, who first introduced the method. Small crushed stones were held together by a natural

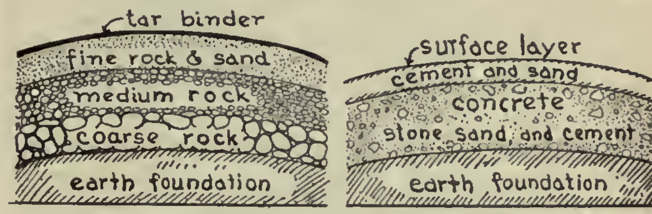


FIG. 486. CROSS SECTIONS OF MACADAMIZED AND CEMENT ROADS

cement of rock dust and water. This type of pavement, while a marked improvement over the older gravel roads, had certain limitations. It was very dusty when dry and could not withstand the heavy traffic of the automobile. This older form of macadam is now being replaced by a more modern type called the bituminous-bound macadam. An excavation is made and a layer of coarse rock is placed in the bottom. This is covered with finer crushed rock and this with fine rock and sand. These are bound with a layer of tar or asphalt applied hot and rolled to smoothness. These roads are sometimes hard surfaced by mixing fine gravel or granite with the tar or asphalt while it is still warm. Figure 486shows a cross section of this type of road.

Portland Cement Assn.

FIG. 487. ROAD BEFORE AND AFTER CEMENTING

Another type of road surface which has become widely used in the past few years is reenforced concrete. These roads are practically wear-resistant and require less upkeep than almost any other type of road surface. Many miles of concrete highway are being

placed yearly in this country. These are paid for largely by the automobile owners in gasoline taxes imposed by the various states.

The cement-road builder first makes and grades an excavation. Upon this a mixture of coarse stone, sand, and cement is placed, often reenforced with iron netting or screening. This foundation is then covered with a surface of sand and cement. Figure 486 shows a cross section of a cement road and Figure 487 a road before and after it was improved with a cement surface.

In some cities wood and stone blocks or bricks are used for paving. These are usually laid upon a base of concrete and bound with tar, asphalt, or cement. In general, these methods of paving are more expensive than concrete or asphalt as is seen by the following table of cost estimates on different types of road. These figures are for 18-foot roads on a basis of 1929 construction costs.

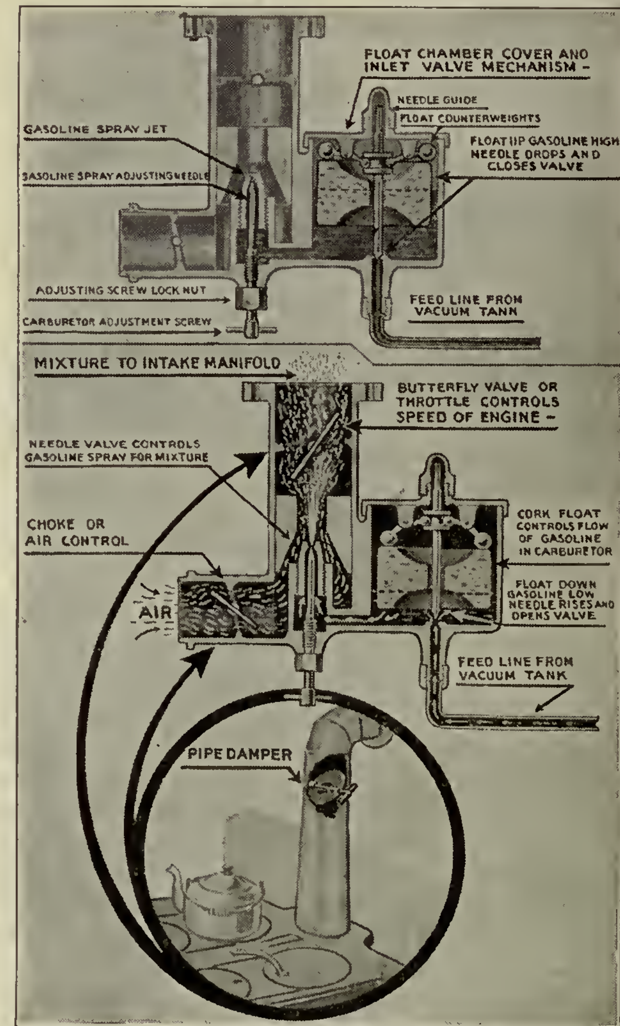
Macadam road, per mile	$16,000
Asphalt concrete, per mile	18,000
Portland cement concrete, per mile	33,000
Brick, concrete base, per mile	45,000
Wood block, concrete base, per mile	70,000

How do the various parts and systems of the modern automobile work together to make it run? The last thirty-five years have seen the development of the automobile from a crude "horseless carriage" to a modern vehicle which has almost displaced the horse as a means of transportation. The automobile has become so common that everyone should know something of the scientific principles that control it. The automobile is made essentially of three systems which, working together, make possible the many uses to which it is put. These systems are the chassis, the power system, and the transmission system.

The chassis. This is the steel framework or foundation upon which the car is built. It also includes the wheels and brakes. Because automobiles are subject to many strains, the chassis must be tough and strong, and, therefore, is built of special steel and is well braced. The chassis is carefully designed and built to carry the load of the car and also to withstand the many strains.

The power plant. This important part of the automobile includes the fuel system, the engine, and the electrical system. An experiment at the beginning of this topic has taught you that when gasoline vapor and air are mixed in a confined chamber, and a spark or flame is introduced, a powerful explosion takes place.

Liquid gasoline is placed in a tank on the car and is fed to the carburetor either by gravity or by air pressure working with a fuel pump or vacuum tank. The carburetor atomizes[1] the liquid gasoline by drawing it through a small jet or opening in much the same way that a throat or perfume spray vaporizes the liquid used in it. After the liquid gasoline has been atomized in the carburetor, it is mixed with air in the correct proportions for a powerful explosion. Figure



Courtesy Standard Oil Co. of New York

FIG. 488. CROSS SECTION OF CARBURETOR (ABOVE); HOW IT WORKS (BELOW)

488 is a cross-section diagram showing the parts of a carburetor and how it sprays the gasoline. The air-gas mixture is taken from the carburetor to the engine through the intake manifold. Figure 489 is a diagram showing the complete fuel system of the car and also how the gas gets from the carburetor to the cylinder of the engine.

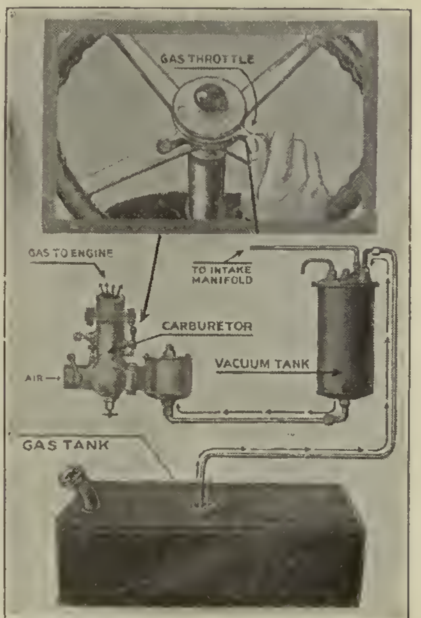
Exercise. *Study Figure 488 and suggest how the pipe damper in a smoke pipe illustrates an important point in the construction and operation of a carburetor.*

[1] *Atomize,* to break up into very small particles. A spray gun atomizes the liquid which it sprays.

Exercise. *In the older type cars where a vacuum tank as shown in Figure 489 was used in the fuel system, a small hole was left in the cap of the gasoline tank. Infer a reason for this.*

The gasoline engine used in the modern automobile is made up of four or more cylinders. Each cylinder is a unit for harnessing the energy of the explosion of the air-gas mixture that takes place inside. Within each cylinder is a tight-fitting piston which moves up and down and which is connected to a crank shaft by a connecting rod.

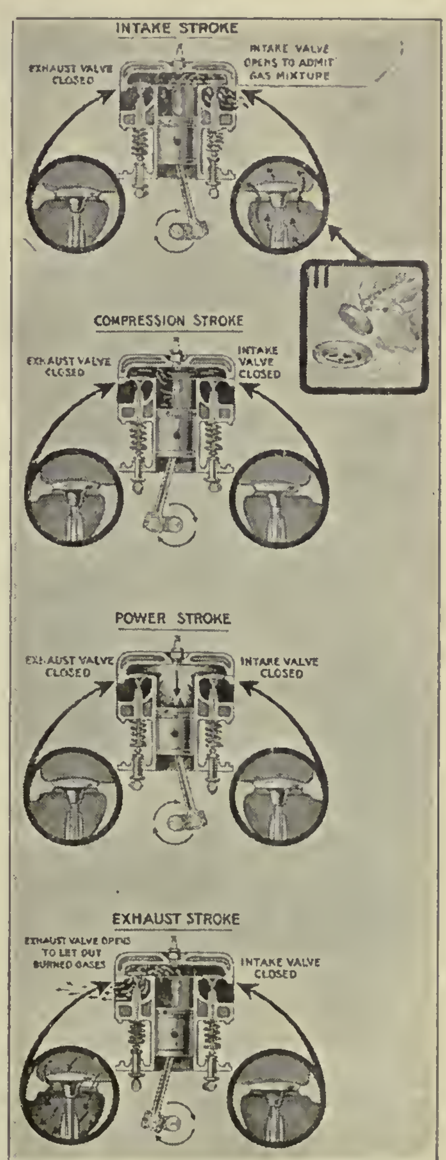
If you understand the construction of the engine you are now ready to learn what happens inside it. The air-gas mixture gets into the part of the cylinder above the piston through the intake valve, and the burned gases are pushed out through the exhaust valve. Follow the diagram (Fig. 490) which illustrates the four strokes through which each cylinder passes every time power is delivered to the crank shaft.



Courtesy Standard Oil Co. of New York

FIG. 489. COMPLETE FUEL SYSTEM OF AUTOMOBILE

As the piston goes down in the cylinder on the first stroke, a low pressure is created. The intake valve opens, and the air-gas mixture is pushed in from the carburetor by pressure. This is called the *intake stroke*. On the next stroke both valves are closed, and as the piston comes up the air-gas mixture is compressed. This is the second or *compression stroke*. Just as the piston reaches the top of the compression stroke an electric spark is sent across the spark plug and the piston is driven down by the force of the explosion. This is the *power stroke*. Notice that both valves are still closed. On the fourth stroke the exhaust valve opens, and as the piston comes up the burned gases are forced out into the exhaust pipe and to the open air. This is called the *exhaust stroke*. As the piston again goes down new gas is drawn into the cylinder and the whole cycle is again repeated. The explosion of the gas develops a very high temperature in the cylinder, and it is therefore necessary to cool the cylinder walls with water. The water is kept cool by being pumped through the radiator where cool air takes the heat away.



Courtesy Standard Oil Co. of New York

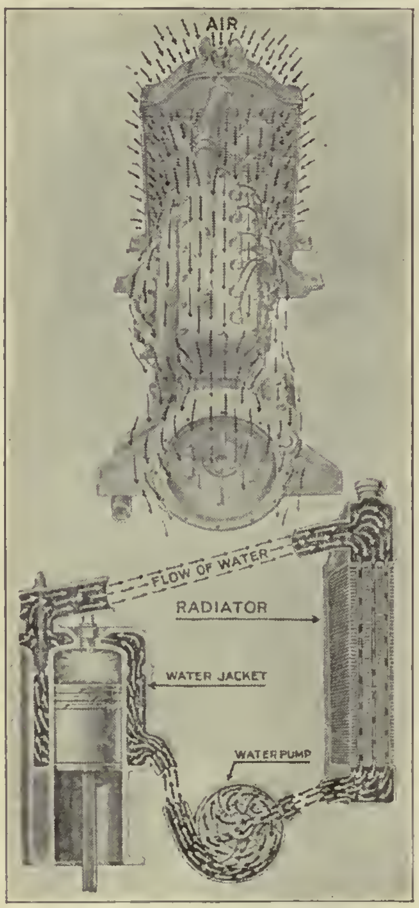
FIG. 490. FOUR STROKES OF THE GASOLINE ENGINE

Exercise. *Study Figure 491 and see whether you can explain how the cooling is accomplished.*

Exercise. *Carefully study Figure 490 and explain what is done when the automobile mechanic grinds the valves of the car. Why must valves be ground? What would result if they were not ground?*

The electric spark which explodes the air-gas mixture is formed by electricity from an electric generator. The electricity is first run through a coil to raise its voltage and is then sent to each spark plug at the exact moment it is needed to explode the gas. This is accomplished by the *distributor*. Figure 492 shows the parts of the ignition system of the car.

Exercise. *Carefully study Figure 492 and explain how the distributor of an automobile works. Briefly explain the use of the distributor in the automobile engine.*



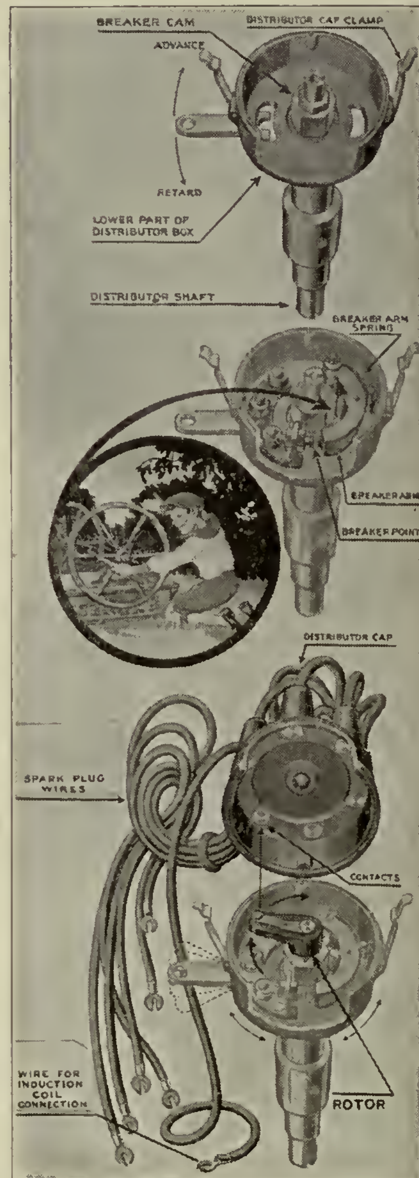
Courtesy Standard Oil Co. of New York

FIG. 491. COOLING SYSTEM OF AUTOMOBILE

The power-transmission system. This part of the automobile transmits the power of the engine to the rear or driving wheels. In the transmission system are included the clutch, the gear shift mechanism, and the differential.

Power is transmitted from the engine to the drive wheels through the clutch, the gears, and the differential. The transmission or shifting gears, located just back of the engine, are connected to the differential in the rear axle by the drive shaft which runs under the car.

The clutch is a device used to disengage the engine from the rest of the transmission system. It consists of two sets of friction plates, one set connected to the engine and the other set to the drive shaft, a part of the transmission system. These two sets of plates, when engaged, are held tightly together by a very strong spring. In this way the power of the engine is transmitted to the drive wheels at the rear.



Courtesy Standard Oil Co. of New York

FIG. 492. IGNITION SYSTEM

When it is necessary to disengage the engine from the rest of the system, the clutch pedal is pushed in, thus separating the two sets of plates and permitting gears to be shifted. Figure 493 shows a cross section of a clutch. Can you find the plates and understand what happens when the clutch lever of the car is pushed?

Exercise. *Carefully study Figure 493. How does the inset in the middle of the picture explain the operation of the clutch? What principle of science is made use*

of in the operation of the clutch on an automobile? Briefly explain the use of the clutch in the power-transmission system of an automobile.

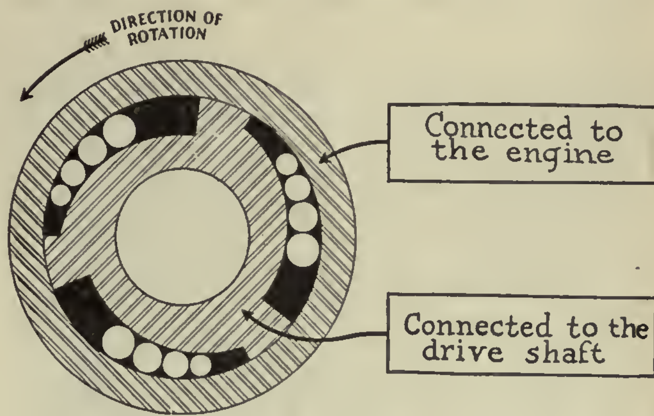
Many of the modern cars are equipped with an automatic clutch or "free wheeling" mechanism, as it is commonly called. This device disengages the engine

Courtesy Standard Oil Co. of New York

FIG. 493. CROSS SECTION OF AN AUTOMOBILE CLUTCH AND HOW IT WORKS

and the drive shaft automatically whenever the engine is turning at a lower speed than the drive shaft as when the car is coasting down hill. Cars that are equipped with the free wheeling mechanism can be changed to the ordinary transmission by the pull of a handle usually placed conveniently on the dash board. Figure 494 explains the operation of the free wheeling device. The outside collar is coupled to the engine while the inside portion is connected to the drive shaft.

Operating in tapered slots between these two sections are three sets of four rollers. When the engine is turning at the same speed or more rapidly than the



Courtesy the Studebaker Sales Corporation

FIG. 494. FREE WHEELING

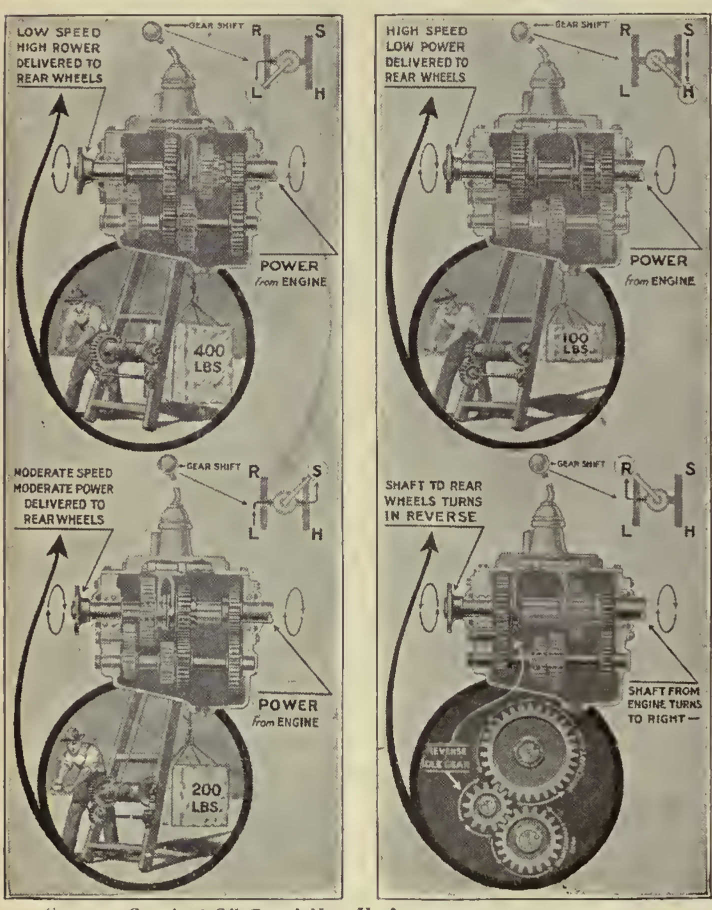
drive shaft, these rollers are forced toward the narrow end of the slots, thus wedging tightly and causing the crank shaft of the engine and the drive shaft to turn as a single unit. If the engine is idling, that is, turning more slowly than the drive shaft, the rollers are forced to the wider ends of the slots, thus automatically disengaging the engine from the drive shaft. During this process the clutch and transmission gears remain engaged. When the free wheeling mechanism is in use gears may be shifted at will without the use of the clutch.

Sometimes it is necessary for the automobile to develop great power while the car is running slowly. This is the case on steep hills and in mud or sand. The sliding gears of the transmisison make this possible. By shifting the proper gears into the transmission system, the car may be driven at a slow, an intermediate, or a fast speed, or the motion of the car may be reversed. This is made possible by engaging gear wheels of various sizes. If two gear wheels of the same size are enmeshed, each turns at the same rate, while if a large gear is enmeshed with a small one, the larger one turns much more slowly than the smaller gear. A car running in high has two gear wheels of the same size meshed; in second gear a large gear wheel is meshed with a small one; in low gear a still larger gear is meshed with a small one. Figure 495 is a series of pictures of a transmission gear system showing the various gears and their positions.

Exercise. *Carefully study Figure 495 and show how the encircled insets of the man using the hoist explain what results when one shifts the gears of a car from "low" to "high."*

In the rear axle of the automobile is located one

of the most important parts of the car. This is called the *differential.* When a car turns a corner or goes around a curve in the road the rear wheel on the outside of the curve must travel faster than the wheel on the inside. This is made possible by placing a complicated system of gears in the center of the rear



Courtesy Standard Oil Co. of New York

FIG. 495. TRANSMISSION GEAR SYSTEM

axle. When the car is moving along a straight road both rear wheels turn at the same rate. Have you ever observed one rear wheel turning while the other is still? This may be seen sometimes when one wheel is lifted off the ground. This is made possible by the differential. Figure 497 shows a picture of the gear system which makes up the differential and how it works. See if you can explain how each rear wheel is enabled to turn independently of the other.

Exercise. *Carefully study Figure 497 and explain how the encircled inset of a column of soldiers marching around a corner explains the operating principle of the differential of an automobile.*

One of the important advances made in the design of automobiles and buses in recent years is an effort to cut down air resistance by streamlining. This is important because modern cars travel faster, and air resistance increases rapidly at higher speeds.

While some manufacturers have gone in for more complete streamlining than others, most cars are now showing models with slanting windshields, pointed

Courtesy Greyhound Lines

FIG. 496. A STREAMLINED BUS

radiators, sharply tapered backs, and fenders designed to create as little air resistance as possible. Figure 496 shows a cut of a modern streamlined bus. It is claimed that streamlining has brought about considerable savings in fuel costs.

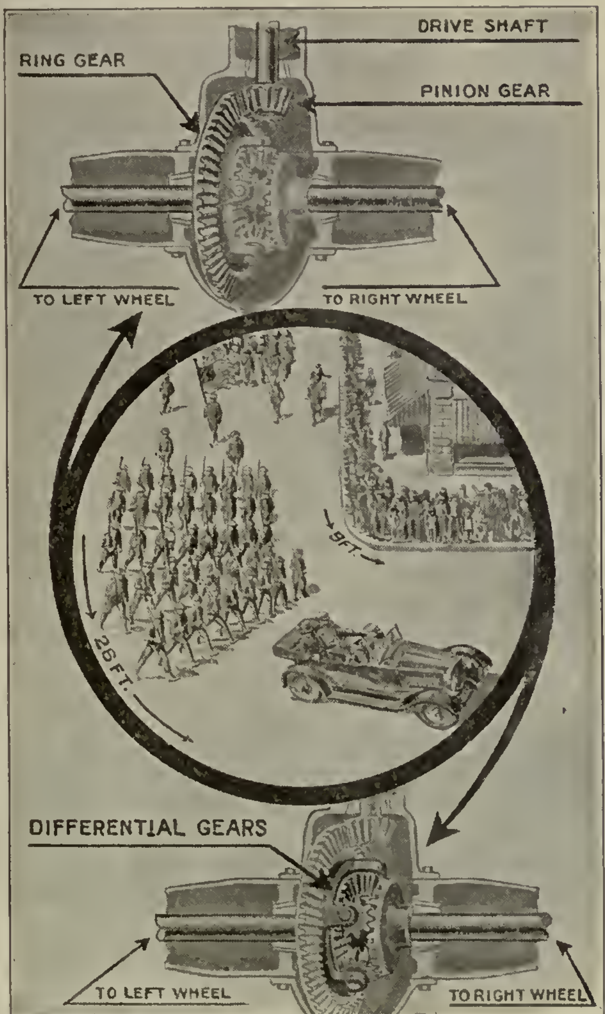
How has transportation by rail been improved? The history of the steam engine has been told in Unit VII, "Man's Use of Machines." James Watt, an instrument maker of Scotland, is given credit for the perfection of the steam engine in its modern form. From an experiment at the beginning of this topic you have again seen that steam, when confined, has energy because of its expansive powers. You have also reviewed the construction and operation of the modern steam engine.

By again referring to Figure 484, check your understanding of the operation of the steam engine. Steam from the boiler enters the steam chest. From the steam chest into the cylinder there are two openings or ports. These are controlled, that is, opened and closed, by a slide valve which operates back and forth over them. When one port is open, live steam gets into the cylinder on one side of the piston and drives the piston with its expansive force. At the same time the other side of the cylinder is connected to the exhaust through the other port. As the piston is driven back by expanding steam the slide valve moves back, connecting the first port with the exhaust and allowing steam to enter the cylinder on the other side of the piston. This piston is attached to a fly wheel through a connecting shaft which is so constructed that it can change the to-and-fro motion of the piston into the rotary motion of the fly wheel.

The earliest application of steam in an engine to run on rails was made by Richard Trevithick in England. His engine was not successful. About 1813 another Englishman, William Hedley, designed and built a locomotive for use in the coal mines, which had very little success because it was too cumbersome. In 1814 George Stephenson, an English inventor, built his first steam locomotive. For fifteen years he improved

this locomotive and in 1829 produced his famous *Rocket*, which was the true beginning of the railroads in England.

In America railroads had their beginning about the same time as in England. In 1827 the Baltimore and Ohio opened a section of road to traffic. The cars were drawn by horses. The first steam power for railroads



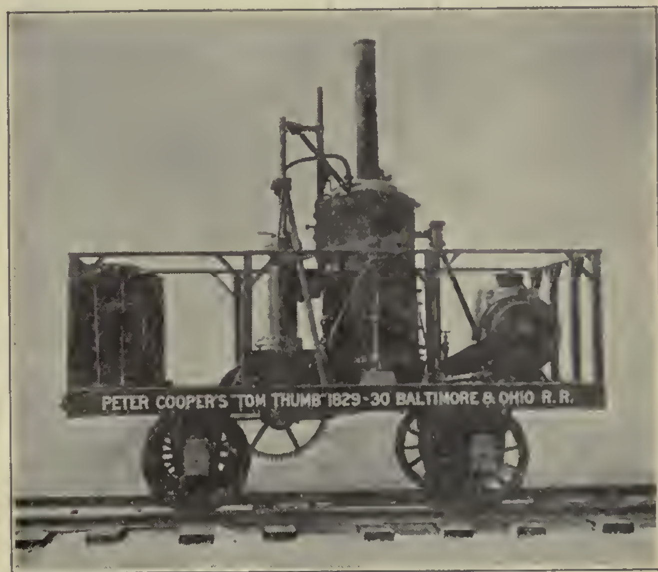
Courtesy Standard Oil Co. of New York

FIG. 497. HOW THE DIFFERENTIAL WORKS

in America was used by the South Carolina Railroad. This road had the first practical locomotive built in this country. It was called the *Best Friend* and was used as early as 1830. Other early locomotives built and used in this country were Peter Cooper's *Tom Thumb* (Fig. 498) by the Baltimore and Ohio and the *Dewitt Clinton* (Fig. 499) by the New York Central.

The modern locomotive, a development from these early engines, is truly an "iron horse." It combines all of the modern developments of steam engines in a single plant capable of developing great power and speed. The modern passenger locomotive has large drive wheels for great speed while freight engines have smaller drive wheels for greater power. Figure 501 shows a picture of a modern freight locomotive. Compare it with the engines of a hundred years ago in Figures 498 and 499.

In a little more than a hundred years railroads have developed in this country until combined they have enough track to go more than seventeen times around



Courtesy Baltimore and Ohio Railway

FIG. 498. TOM THUMB

the earth at the equator. The rapid growth of this country would have been impossible without the development of the railroads for transporting raw materials, finished products, and labor.

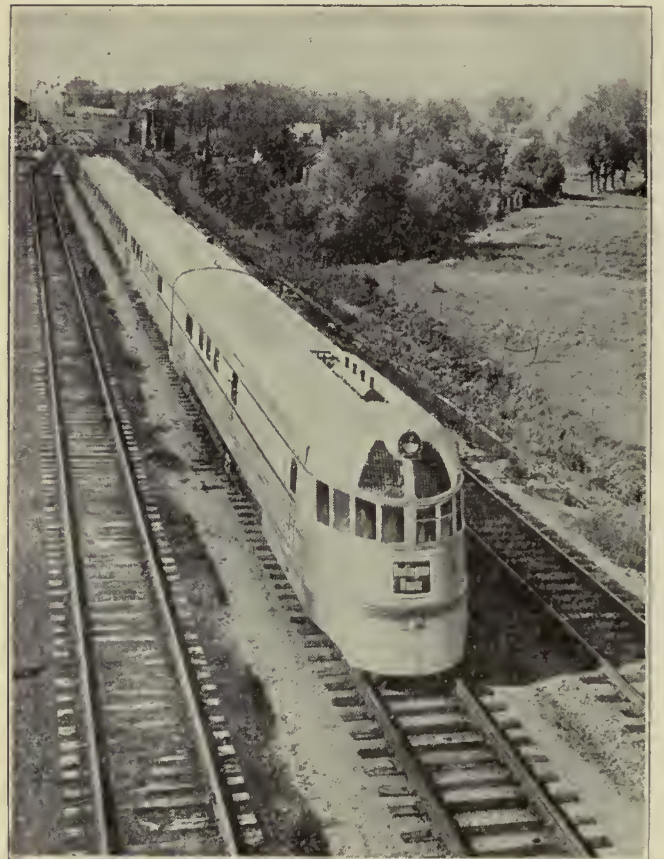
Courtesy New York Central Railway

FIG. 499. THE DEWITT CLINTON

A very few years ago, if one wished to go any distance on land, the only means of transportation was by railroad. In many instances the trip was slow, dirty, and monotonous. Then buses came into the transportation picture. A network of bus lines covered the country and afforded a means of transportation that was clean, comfortable, interesting, rapid, and cheap. Many people who had formerly traveled only

by rail began to use the buses with the result that passengers decreased in numbers on the trains.

Along with the buses airlines have also developed, and our modern airliners are carrying thousands of passengers each year. This again has taken considerable traffic from the railroads.



Courtesy Burlington Route

FIG. 500. A STREAMLINED TRAIN

As a result of these developments in new modes of land travel, the past few years have seen some most interesting developments in rail transportation. The railroads are investing millions of dollars in new equipment in an attempt to regain their former position of supremacy in land transportation. Some of our most modern trains seem to belong to another age, they are so different from the ones that we are so accustomed to using.

One of the principal points of competition which the railroad faces in the airplane and bus is that of speed. Modern trains are being built to attain much higher speed than was possible before. Speed has been increased in several ways. First the use of aluminum and aluminum alloys has made it possible to decrease the weight of the train. Modern trains have followed the example set by the automobile and bus manufacturers with streamlined designs. The whistle and bell, commonly seen on the top of the older style locomotives, have been set back in the body of the car. Vestibules are closed and the steps pull up when not in use.

One of the most radical departures in the new-type train is the power plant. Instead of coal as a fuel, many of them are using oil. The oil is used to drive Diesel engines which in turn are used to turn electric generators. The electricity resulting is then used to drive electric motors that propel the train. This not only enables more efficient use of the energy in the fuel, but enables higher speeds and furnishes a supply of power which is free of dirt and which is easily controlled.

The fact that these trains are able to reach much higher speeds and maintain them over long distances is evidence of their superiority over the older trains.

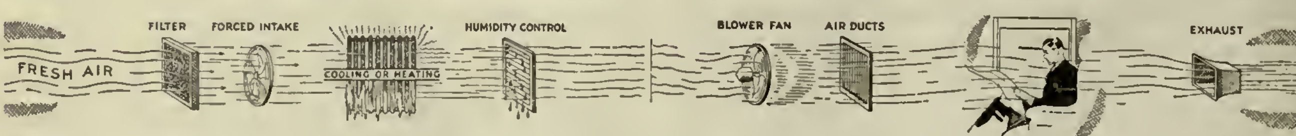
Another significant advance in rail transportation in recent years has been the air conditioning of trains. On many lines today the air supplied to the cars is cleaned and either heated or cooled, depending upon the outside temperature. Figure 500 shows a modern streamlined train and Figure 502 shows how railroad cars are air-conditioned.

Courtesy Baldwin Locomotive Works

FIG. 501. MODERN FREIGHT LOCOMOTIVE

Exercise. *Trace the mechanical energy of a Diesel electric train to its remotest source through all of its transformations.*

Of what importance is electricity in modern transportation. Experiments in electrical transportation were carried on in this country as early as 1835, but



Courtesy The Pullman Company

FIG. 502. HOW A RAILWAY COACH IS AIR-CONDITIONED

proved a failure because the car depended upon batteries for its electrical energy. The development of the electric generator and ways of distributing the energy gave modern electrical transportation to the world. The first overhead trolley system was built in Kansas City, Missouri, but the first city to replace the old horse-drawn cars with electrically propelled cars was Richmond, Virginia. Modern street railway transportation dates from the Richmond experiment about 1887.

In the modern overhead trolley system electrical energy is obtained from generators in a power house, distributed through overhead wires. The car has a trolley wheel at the end of an arm extending above the car. This wheel runs along the supply line and thus connects the electric motors of the car with the electrical supply. The rails and earth form a return circuit to the power house for the electricity. Between the trolley and the motors of a car is placed a resistance which can be controlled by a lever in front of the motorman. The resistance in the circuit may be increased or decreased by moving the lever. When the car is to be slowed, more resistance is placed in the circuit and less current can reach the motors. When the car is to be speeded up resistance is removed from the circuit and more current reaches the motors. Motors used on street cars are geared directly to the wheels.

Brakes on the modern street car are of the air type and are controlled by a lever in front of the motorman. Doors on many modern street cars are also opened and closed by means of compressed air.

In several of the larger cities of this country and Europe electrically propelled trains are used for rapid transportation on elevated lines and in subways. In place of the overhead trolley these systems usually use a third rail to carry the electrical energy from the power house. The third rail is placed beside the track. The cars have an extension arm and a metal shoe which rides along the third rail, much as the trolley wheel moves along the trolley wire.

On some of the railroads in the mountainous sections of the West electric locomotives have replaced steam. On the steep mountain grades the electric locomotives are able to move more heavily loaded trains at a greater speed than the steam locomotives. The locomotives used on these trains are electric power houses on wheels. While the locomotive is climbing a grade it is taking current from the overhead line to drive its powerful motors. When the top is reached and the train starts down the other side, use is made of the force of gravity to move the train. The motors which propelled the train up the mountain now become generators and give back to the line nearly 30 per cent of the electrical energy which they used in climbing. This also serves as a braking device while descending the steep grades. Figure 503 is a picture of a modern electric locomotive in use.

In several large cities of the country railroads have electrified their lines. This makes for much cleaner and more efficient handling of trains.

Courtesy the Milwaukee Road

FIG. 503. MODERN ELECTRIC LOCOMOTIVE

The most recent addition to the devices for land transportation is the bus. It is possible to reach almost any point in the country by buses which run on nearly as exact schedules as the trains. On some lines it is possible to secure sleeping accommodations.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 28

Clement, Collister, and Thurston, *Our Surroundings*, Chap. 19

Hunter and Whitman, *Science in Our World of Progress*, Unit 9

Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 25 (part)

Pieper and Beauchamp, *Everyday Problems in Science*, Unit 17

Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 20

Webb and Beauchamp, *Science by Observation and Experiment*, Unit 3

Wood and Carpenter, *Our Environment: How We Use and Control It*, Topic 11 A

Special references

Book of Popular Science

The World Book

Compton's Pictured Encyclopedia

Holland, *Historic Railroads*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. An understanding of the method of construction of macadam and cement roads.
2. An understanding of the following things about the automobile:
   The principles involved in the power system.
   The principle of the clutch and transmission.
   The principle of the fuel system.
   The principle of the differential.
3. A knowledge of the importance and development of railroads in the United States.
4. A knowledge of how electricity is used in land transportation.
5. The importance of the bus in transportation.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The steel framework upon which the automobile is built is called the ____.
2. In the carburetor of the automobile ____ fuel is changed to ____ and mixed with ____.
3. When the carburetor is "choked" ____ is shut out.
4. The valve in the carburetor which keeps the level of liquid gasoline always the same is the ____ valve.
5. What happens when the carburetor is flooded?
6. A ____ voltage electric current is necessary to make a spark jump across a spark plug.
7. The power stroke of the automobile follows the ____ stroke and is followed by the ____ stroke.
8. What is the clutch and what does it do in the operation of the car?
9. The transmission of an automobile is made up of ____. Explain what it is used for.
10. The differential of an automobile is located ____. It enables ____.
11. Explain how macadam roads are built.
12. Why are cement roads superior to macadam roads?
13. ____ moves back and forth in the cylinder of a steam engine.
14. Steam enters the cylinder of a steam engine from the ____ through ____ openings.
15. The slide valve moves back and forth in the ____ of the steam engine.
16. When one part of the steam engine cylinder is receiving live steam the other side of the piston is connected to the ____.
17. Write a paragraph on the importance of the railroads in the development of the country.
18. Some of the early locomotives constructed in this country were named ____.
19. Trains, electric cars, and many buses are stopped by means of ____ brakes.
20. Write a paragraph on the advantages of bus travel.
21. Trolley cars are run by electric ____.
22. Electric current from a trolley car gets back to the generating station through the ____ and the ____.
23. Write a paragraph on the advantages and disadvantages of the electric locomotive.
24. A recent development in automobiles, buses, and trains that has tended to increase their speed and decrease fuel consumption is known as ____.
25. Another improvement in trains that has also tended to increase their speed is the use of ____ in their construction.

TOPIC 2. TRAVEL ON WATER

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is the history of transportation by water?**
2. **Why do some substances float and others sink?**
3. **What is stability and what are the factors that affect it?**
4. **How are modern ships propelled?**
5. **How are submarines enabled to sink and rise in water?**

SUGGESTIONS AND HELPS FOR STUDY

1. Read the problems and questions carefully before you try to solve them. It is quite likely that most of your information for this topic will have to be obtained from textbooks. If, however, you have the opportunity to inspect any types of boats, do so and gather all the first-hand information that you can.

2. Examine carefully all the pictures and diagrams given in this textbook and others in connection with methods of water transportation. They will help you understand the principles involved in water transportation.

3. Study the following words and definitions. They will help you in understanding this topic.

stability—the state of being firm or steady, so as not to be easily tipped over.
buoyancy—a force supporting a floating body.
gravity—the pull of the earth upon objects.
ballast—any heavy substance put into the hold of a vessel to make it stable.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 177. Why does a boat, made of a substance heavier than water, float?

Roll a piece of lead foil into a ball and place it in water. Why does it sink? Now unroll the ball of lead foil and

[1] See workbook, p. 109.

bend up the sides so as to make a boat. Place it in water. Why does it float?

When a body floats it pushes out or displaces (more, less) ____ water than when it sinks.

Experiment 178. Why do some substances float while others sink in water?

a) Secure a container such as the one shown in Figure 504 which may be used as an overflow can. Also secure a small basin which may be used to catch any overflow water, and a spring balance. Carefully weigh the catch basin and record its weight. Weigh a piece of iron in air and record its weight. Fill the overflow can as full of water as possible and lower the iron weight suspended from the balance into the can. Read the balance and record the weight of the iron in water. Weigh the catch basin and water and record their combined weight. Calculate the difference of weight of the iron in air and in water. Find the weight of the water displaced.

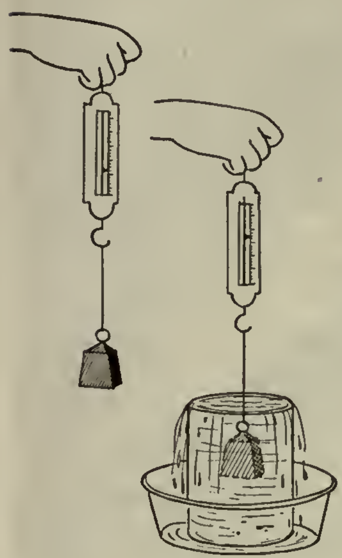


FIG. 504

b) Repeat the experiment with a piece of wood which will float. Record your results as in part *a*. Complete the following statements.

Bodies which sink in water displace an amount of water whose weight is equal to their ____ of weight from ____ to water.

Floating bodies appear to lose ____ of their weight in water. Floating bodies displace water equal to their weight in ____

Both floating and sinking bodies appear to be ____ up by a force when they are in water. This force seems to be equal to the weight of water which they ____.

Activity 179. Inspection of some modern boats.

If there are any water transportation lines in or near your community, visit a dock and inspect the types of boats being used. Try to find answers to the following questions.

How are they propelled through the water? How are they steered? What kinds of engines are used?

Experiment 180. How does the gyroscope work?

Cut a disk five or six inches in diameter from a piece of metal or from an old tin can. Locate the center accurately and punch a small hole at this point with a nail. Tie a large knot in the end of a piece of string and pull the string through the hole so that the knot holds the disk.

Swing the disk back and forth like a pendulum and observe how it behaves. Now set the disk rotating rapidly about the string and again swing it like a pendulum. Experiment with different positions of the disk. What differences do you notice in the behavior when the disk is spinning and when it is not spinning? Can you observe any tendency on the part of the spinning disk to resist a force that tends to change its plane of rotation?

Plan a further experiment to test this point. *Suggestion:*

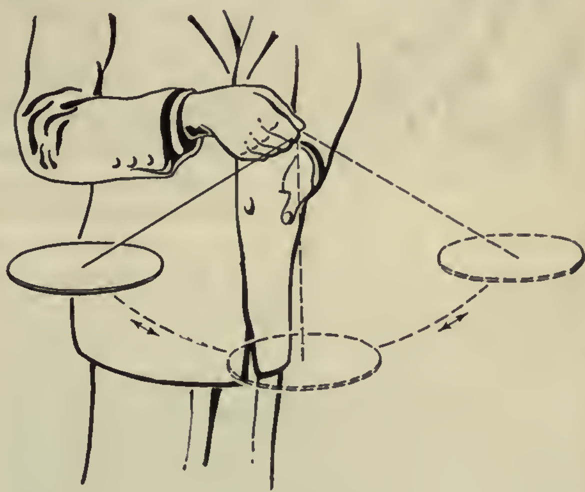


FIG. 505.

Try blowing on the spinning disk through a rubber tube. Does the disk tip up at the point where the air blast strikes it? How far away from this point does it tip up? Can you suggest how such a rapidly rotating body might be of use in preventing the rolling of a ship at sea?

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

What is the history of transportation by water? The savages of long ago, no doubt, were the first to use water to get from one place to another. The first boat was probably a floating log with the passenger astride. Later it was found that groups of logs fastened together in a raft could be used to transport several persons at the same time. The log boat and the raft were heavy and difficult to handle. To make a lighter craft, the inside was burned out of the log boat to make the first dugout. As skill and daring developed man made the first bark canoe and then larger and larger boats until today we travel on liners which are floating hotels with every comfort.

The earliest boats were propelled by man power until the development of the sailboat which used the force of the winds. From about 1000 A.D. down to the use of the steam engine, the sailboat went through many stages of development. From the combination man-and-wind-power ship of the tenth century to the clipper ship of the nineteenth century is a story of progress with few equals.

FIG. 506

The steam engine was first applied to water transportation in 1803 when Robert Fulton, an American inventor working in Paris, launched a boat driven by steam on the Seine River. In 1807 he built and launched the *Clermont* (Fig. 507) on the Hudson River and was soon able to open a packet line between New York and Albany.

The Atlantic Ocean was first crossed by a steam propelled ship, the *Savannah,* in 1819. Regular passenger service was established between England and America in 1838 when the liner *Great Western* was put into service. The journey required fifteen or sixteen days. Comparison of this time with that of five or six days required by the modern liner tells the story of progress of the past century in ocean travel. Figure 508 shows one of the most modern of ocean liners, the *Queen Mary.*

The two largest ships afloat are the *Normandie,* owned by the French Line, and the *Queen Mary,* owned by the Cunard-White Star Line. The *Normandie* is 1,029 feet in length and has a displacement of 79,000 gross tons. The *Queen Mary* is 1,018 feet long and has a displacement of 83,000 gross tons.

FIG. 507. THE *Clermont*

Why do some substances float and others sink? Objects appear to be lighter when they are submerged in water than they are in air. Have you ever observed how much easier it is to lift a heavy stone under water than it is to lift the same stone out of water.

Paul's Photos

FIG. 508. THE *Queen Mary*

The principle of buoyancy was first studied and explained by Archimedes, a Greek mathematician and scientist who lived from 287 to 212 B.C. in the city of Syracuse on the island of Sicily.

The story is told that King Heiron of Syracuse employed a goldsmith to make a crown of pure gold. When the crown was delivered the king had reasons to believe that the goldsmith had not made the crown of pure gold but had used part silver, keeping the remaining gold. The king had become a close friend of Archimedes and so asked him if there was some way in which he could tell whether the crown was pure gold without cutting into it. Archimedes spent some time working on this problem and one day while taking a bath in the public baths he observed that his body displaced water. He at once applied this knowledge to the solution of the problem of the crown and found that the goldsmith had defrauded the king. Archimedes was also the discoverer of the principle of the lever. See page 158.

The experiment at the beginning of this topic has

taught you that bodies which are submerged or float in water experience an upward push which makes them appear to have lost weight. You have also learned from the experiment that the upthrust or force experienced by either a floating or a submerged body is equal to the weight of water displaced.

FIG. 509. A FLOATING BODY DISPLACES ITS WEIGHT

When a floating body is weighed in water it is found that the water supports all the weight of the object. Any substance can be made to float if it can be shaped into such a form that it will displace its own weight of water. Iron, steel, and concrete all will sink in water when in compact forms, and yet if they are so shaped as to have large displacement they can be made to float.

The displacement of a ship is the weight of water which it will displace when fully loaded with cargo and passengers. Since a floating body displaces its own weight of water, the water displaced will be equal to the total weight of ship and cargo. By knowing the material from which a ship will be built and the weight of the equipment, engineers can calculate the carrying capacity of a ship before it is built.

FIG. 510. CENTERS OF GRAVITY, BOAT AND CANOE

What is stability and what are the factors that affect it? A canoe can be tipped over much more easily than a flat-bottom rowboat. This is because the rowboat has much greater stability than a canoe. The stability of a boat depends upon several things. If a body has a broad base area, like the rowboat, it has greater stability than one which has a smaller base area. Another important factor in stability is the position of the center of gravity. The center of gravity of any body is the point where all of its weight may be thought of as concentrated. A uniform plank, for example, has its center of gravity in the middle, while a plank thicker at one end has its center of gravity nearer the thick end. In general, the center of gravity of a solid body is the point where it would balance. However, in the case of a chair the center of gravity would fall somewhere in the air below the seat. In a boat the center of gravity would be in the air above the bottom. Study Figure 510.

The position of the center of gravity is important in stability. If the center of gravity of a boat is high or if it is shifted to one side, the stability is lessened and the boat is more easily tipped over. In the case

Courtesy Busch-Sulzer Bros.

FIG. 511. THE *Aorangi*, A DIESEL-POWERED SHIP

of the canoe with a person sitting in it, the center of gravity is much higher than in the rowboat. This, of course, makes the stability of the canoe much less. Study Figure 510.

In shipbuilding and in general ship transportation every effort is made to keep the center of gravity low. Racing sailboats have extremely high masts which would tend to raise the center of gravity and make for an unstable condition. This is offset, however, by building a keel which extends far below the bottom of the boat and may be weighted. Many freight ships carry ballast of rock or sand in the bottom of the boat to increase their stability.

Exercise. *At a summer camp a boy was sent to a town across the lake with a canoe to transport a heavy iron casting which had been sent to that point for the camp. As the lake was rough, the boy was afraid that if he placed the heavy casting inside it would tip the canoe over or break the thin supports in the bottom. A man at the dock suggested that the casting be suspended under the canoe in the water by means of a rope for safe trans-*

portation. Did the suggestion have any scientific basis? Was it a good suggestion? State reasons for your answer one way or the other.

How are modern ships propelled? While the steam engine is still much used as a source of power, the steam turbine is coming more and more into use on modern ships. Since turbines are not reversible, they must either be in pairs or, as is usually the case, used to turn electric generators which furnish current to electric motors attached to the propellers. These can be easily reversed.

Courtesy Sperry Gyroscope Company

FIG. 512. GYRO COMPASS

Coal as a fuel on ships is being replaced by oil not only because it is cleaner but also because of the saving in space needed for fuel storage. Many large ocean-going vessels are equipped with oil burners.

Oil is also used as fuel on those vessels which are driven by Diesel engines. These have been used as a source of power on vessels up to about 30,000 tons displacement. The Diesel engine differs from the ordinary gasoline engine in that it uses the heat developed in compression to explode the fuel rather than an electric spark. Figure 511 shows a cut of a modern ocean-going vessel equipped with Diesel engines.

For ocean travel, the side and stern drive wheels have long since been replaced by the screw propeller. These can be turned much more rapidly and thus can drive the boat with greater speed. Some of the most modern of ocean liners have two, three, and sometimes four screw propellers.

In Unit XI you learned that the earth is a large magnet and that as a result compasses point northward. Until recent years ocean transportation was dependent upon the magnetic compass to point the direction for voyages.

Exercise. *Explain briefly why the magnetic compass does not point true geographic north. If you are unable to do this, turn to page 246 and review the section on the magnetic compass.*

Exercise. *Often the magnetic compass on steel vessels is found to be in error. Can you infer a cause for this condition? Suggest a simple way in which it might be corrected.*

How is direction told at sea? If you have ever played with a gyroscope top, you are familiar with the tricks that it can perform because of the rapidly turning weighted wheel. A body such as this when spinning rapidly tends to resist any force which attempts to change the line of the axis of rotation. This principle has been applied in stabilizing ships to prevent rolling in rough water. Another application is made of the action of the gyroscope in the gyroscopic compass, invented by Sperry, an American. In combination with the spin of the earth on its axis this instrument acts to point true north. The mariner's compass, on the other hand, points magnetic north and is, therefore, subject to the variations of the earth's magnetism and those caused by iron and steel used in the construction of the ship. Figure 512 shows a picture of a gyro compass.

How is the submarine enabled to sink and rise in water? This type of boat has been used chiefly as an instrument of war and probably will continue so, inasmuch as its value as a means of transportation seems limited. The first submarine is believed to have been built by a Dutchman by the name of van Drebble. In 1624 he exhibited his craft in the Thames River at London. It is said to have been built of wood and propelled by oars. Robert Fulton experimented with a cigar-shaped submarine before building the first steamboat. He succeeded in staying under water in his craft for five hours.

The modern submarine dates from 1877 when John P. Holland, an American, built the first under-water craft which seemed to have prospects of developing into an effective weapon of war. Since that time it has been developed until now a modern submarine may be three hundred fifty feet in length. Figure 513 shows a modern submarine.

The submarine is able to submerge or rise to the surface at the will of the commander of the boat.

When it is to be submerged, water is pumped into tanks, thus adding weight to the boat. Submerging is aided by means of fins which can be tilted in such a manner as to throw the front end down. When the boat is to be brought to the surface compressed air is forced into the tanks and the water is forced out. This makes the boat a floating body, and it rises under the influence of the buoyant force of the surrounding water. The rising of the boat to the surface is also aided by so tilting the fins that the front end of the boat is thrown upward. When a submarine is on the surface it is propelled by Diesel engines and when

International Newsreel

FIG. 513. THE U. S. NAVAL SUBMARINE *Nautilus*

submerged it is propelled by motors run from storage batteries.

Exercise. *Infer a reason why the submarine uses electric motors rather than its Diesel engines for power when it is submerged.*

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Taday,* Chap. 28
Clement, Collister, and Thurston, *Our Surroundings,* Chap. 20 (part)
Hunter and Whitman, *Science in Our World of Progress,* Unit 9
Lake, Harley, and Welton, *Exploring the World of Science,* Chap. 25 (part)
Pieper and Beauchamp, *Everyday Problems in Science,* Unit 17
Van Buskirk and Smith, *The Science of Everyday Life,* Chap. 20
Webb and Beauchamp, *Science by Observation and Experiment,* Unit 3
Wood and Carpenter, *Our Environment: How We Use and Control It,* Topic 11 B

Special references

Bachman, *Great Inventors and Their Inventions*
Campton's Pictured Encyclopedia
Chatterton, *The Ramance of the Ship*
Collins and Collins, *Boys' Book of Submarines*
Miller, *Canoeing, Sailing, and Motor Boating*
Bishop, *The Story af the Submarine*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Something of the development of water transportation.
2. An understanding of the principle of Archimedes.
3. An understanding of the principle of stability and the factors which control it.
4. An understanding of how modern ships secure their power.
5. A knowledge of the importance of the gyro compass to modern water transportation.
6. An understanding of how the submarine applies the principle of Archimedes.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions and comply with the instructions.

1. The lifting force of water is called ____.
2. Floating bodies appear to lose ____ their weight when placed in water.
3. ____ and ____ are used to furnish power for modern ships.
4. Explain what is meant by center of gravity.
5. When submerged in water sinking bodies appear to lose weight equal to the ____ of ____ displaced.
6. Stability means ____ when referring to a ship.
7. The stability of a boat in water depends largely upon the ____ of the center of gravity.
8. The gyroscope is used on ships to prevent ____.
9. The use of the gyroscope for this purpose depends upon its tendency to ____ any change of ____ of its axis of spin.
10. When a submarine is under water it is driven by ____ run from large ____.
11. The ____ of the submarine aid in rising and submerging.
12. ____ discovered the principle of buoyancy.
13. Ships are driven through the water by means of ____ propellers.
14. Ships are steered by means of ____.
15. Write a paragraph setting forth the important stages in the development of water transportation.
16. Sinking and floating bodies are buoyed up by a force equal to the weight of ____.
17. ____ developed the first steamship.
18. Write a paragraph on the advantages and disadvantages of waterways as means of transportation.
19. Passenger ships are built high out of the water and slim, while freighters are built close to the water and broad. Explain.
20. The compass may be used to point direction because the ____ is a large ____ and has ____ of force about it.
21. The magnetic compass does not point true north because the ____ poles of the ____ are not at the ____ poles.

TOPIC 3. TRAVEL IN THE AIR

SUGGESTED PROBLEMS AND QUESTIONS

1. **What is the history of the balloon?**
2. **What are the various types of dirigible balloons, and what principles control them?**
3. **What is the history of heavier-than-air devices?**
4. **Why does the airplane stay up?**
5. **How is the airplane controlled?**
6. **What are some of the achievements of the airplane and the dirigible?**
7. **What are some of the recent developments in aviation?**
8. **Of what importance are the dirigible and the airplane in modern transportation?**

SUGGESTIONS AND HELPS FOR STUDY

1. Great developments are taking place in the field of aviation. In this topic you will have an opportunity to learn about the basic principles of air transportation.

2. Many newspapers and magazines contain information about dirigibles and airplanes. Sometimes they give directions for building small model planes. Have you ever tried to build a model of an airplane? Try it.

3. The following words may be new to you.

hydroplane—an airplane built to land on water.
rudders—devices used to guide an airplane.
ailerons—movable pieces attached to the outer ends of the wings of an airplane.
helium—one of the lightest known gases, which is now being used in dirigibles in this country.
helicopter—an airplane which can rise straight from the ground or be landed in a small space. This is made possible by a large revolving propeller placed on top of the plane. See Figure 525.

EXPERIMENTS OR DEMONSTRATIONS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS[1]

Experiment 181. Why does a balloon rise?

Make a thick soap solution by dissolving soap in warm water. Attach a short length of glass tube to a gas jet or a hydrogen generator by means of a rubber tube. Blow bubbles with the gas and detach them from the tube by a slight jerk. Observe what happens.

Fill a rubber balloon with hydrogen gas. This may be accomplished by first filling a large bottle with the gas and then using water pressure to force the gas into the balloon. See Figure 514. Fill another balloon with carbon dioxide. What happens in each case?

Record your observations and answer the following questions.

Why does the balloon filled with hydrogen behave as it does? Why does the balloon filled with carbon dioxide behave as it does? What gases are used in dirigibles?

Activity 182. What notable flights have been made?

Prepare a list of great flights that have been made in airplanes and dirigibles. Give the names of the fliers, date of the flight, type of machine, and a brief description of the flight. Collect pictures of the fliers and the machines in which these flights were made.

READINGS WHICH WILL HELP ANSWER THE PROBLEM QUESTIONS

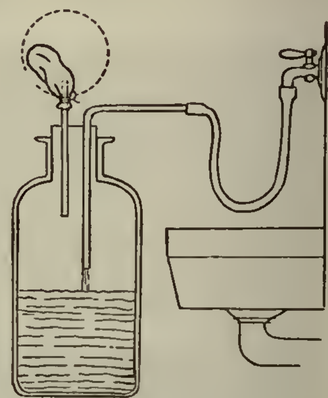


FIG. 514

What is the history of the balloon? In this age of aircraft it seems strange that the ancient Greeks were among the first to think of the use of air for transportation. Records show that Archytos, a Greek scholar of the fourth century before Christ, constructed a wooden bird for the purpose of flight. It is interesting to note that from the dreamings and crude experiments of these early Greek philosophers no practical results came until the eighteenth century, when the balloon was invented.

The invention of the balloon is commonly credited to the Montgolfier brothers, Frenchmen. In 1783 they inflated and raised the first balloon. Before this, however, Cavendish, an Englishman, had discovered hydrogen, the lightest of the elements, and had predicted that light bags filled with this gas were sure to rise. Before resorting to the gas from burning straw and wood to fill their silk balloons, the Montgolfiers had experimented with hydrogen in paper bags. After these experiments they made a larger balloon and

Courtesy Goodyear Tire and Rubber Company

FIG. 515. NON-RIGID DIRIGIBLE

[1] See workbook, p. 112.

late in 1783 sent it up into the air carrying several animals. These returned to the earth safely, and a short time later Rozier and d'Arlandes, Frenchmen, made a flight over Paris, staying in the air about twenty-five minutes and covering a distance of five miles.

Ballooning spread throughout the world as a sport and has remained so to the present day. Each year an international balloon race is held with entries from many countries. The record distance for free ballooning is 1,354 miles made in 1912 by Maurice Bevaims, a Frenchman.

Courtesy Goodyear Tire and Rubber Company

FIG. 516. SEMI-RIGID DIRIGIBLE

Balloons have been of great use for purposes of observation in war and for the study of the upper atmosphere. In recent years great progress has been made in the exploration of the upper atmosphere by means of balloons. Professor Piccard of Belgium ascended to an altitude of ten miles above the earth's surface in 1932. Since that time three other ascents have exceeded Piccard's altitude. Three Russian scientists reached 11.4 miles in September, 1933; two Americans, Settle and Fordney, reached 11.6 miles in November of the same year; and in November of 1935 two other Americans, Stevens and Anderson, reached the record altitude of 13.7 miles.

What are the various types of dirigible balloons, and what principles control them? In free ballooning the altitude of the balloon may be controlled by the pilot. The balloon may be raised by throwing out ballast in the form of sand or it may be lowered by allowing gas to escape through a valve. The direction which a free balloon will take, however, is dependent largely upon the wind.

As early as 1852 a Frenchman, Henri Giffard, made a flight in a cigar-shaped balloon 143 feet long and 39 feet in diameter. The balloon was driven at the rate of six miles an hour by a three-horse-power steam engine connected to a screw propeller. The ship could be controlled not only for altitude but also for direction. This was the first dirigible balloon.

Following this pioneer dirigible, many attempts were made to perfect it as a means of transportation, but the chief difficulty was the lack of suitable motors. The modern dirigible had to await the perfection of the gasoline engine.

There are three types of dirigible balloons. They are the non-rigid, the semi-rigid, and the rigid. In the first, a cigar-shaped bag is filled with gas; the second is a gas-filled bag reenforced by wire netting and some metal attachments. Sometimes it has a brace of duralumin (a light alloy of aluminum) running from one end to the other. The third type is the rigid dirigible and is built usually on a structural framework of duralumin. Figures 515, 516, and 518 show dirigibles of these types.

The first rigid dirigible was built by Count Ferdinand von Zeppelin in 1900. The framework was built of aluminum, and it contained seventeen gas compartments inside the huge bag, which was 406 feet long and thirty-eight feet in diameter. It held 400,000 cubic feet of gas. Since 1900 the dirigible has undergone many improvements. The *Graf Zeppelin*, a modern dirigible built in Germany, shows some of the advances. The framework of this modern Zeppelin is built of duralumin, a new alloy which is better than pure aluminum because it is just as light and much stronger. It is 770 feet long, 115 feet high, and 102 feet in diameter and holds 3,708,000 cubic feet of gas. It has a cruising speed of eighty miles per hour. Figure 517 shows an early Zeppelin.

After the *Graf Zeppelin* was built in 1927, two larger ships, the ill-fated *Akron* and the *Macon*, were built in this country for the United States Navy. The *Akron*, which was destroyed in a storm with the loss of seventy-three lives in April, 1933, was 785 feet in length and 132.9 feet in diameter and had a gas capacity of 6,500,000 cubic feet. The *Macon*, sister ship of the *Akron*, completed in 1933, was slightly larger. The *Macon* was later destroyed.

Recently the *Hindenburg*, the largest lighter-than-air craft, was built in Germany. This ship has a dis-

Courtesy Goodyear Tire and Rubber Company

FIG. 517. AN EARLY ZEPPELIN

placement of 7,063,000 cubic feet and a total lift of 472,940 pounds. The lift capacity of this balloon equals the weight of a steam locomotive or five loaded freight cars.

All balloons depend upon the principle of buoyancy. In the preceding topic you learned that water transportation was made possible by the principle of buoyancy. That study taught you that whenever a body is placed in a liquid it is pushed up by a force which is equal to the weight of the liquid displaced by it. If the body weighs more than the liquid it displaces, it sinks, while if the body weighs the same as the liquid it displaces, it floats.

International News Photos

FIG. 518. THE *Hindenburg*

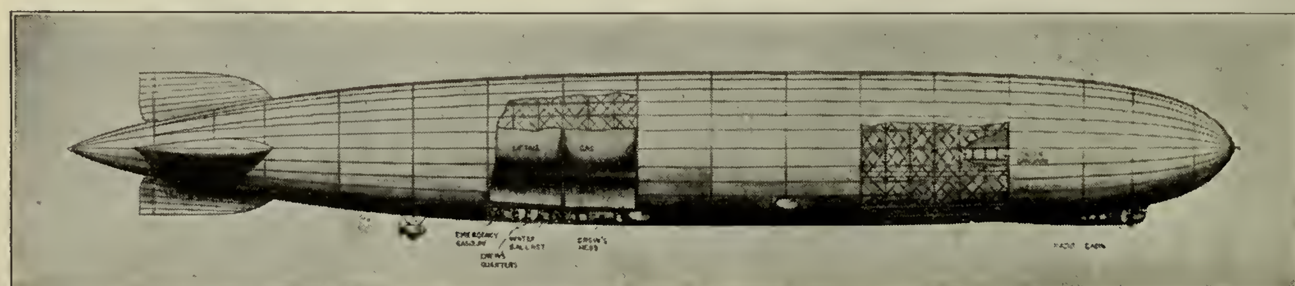
In the case of dirigible balloons the same principle holds true. Balloons and dirigibles are known as lighter-than-air craft; that is, they are able to float in the air because the air displaced weighs as much as the balloon and its load.

Dirigible balloons are very heavy and must therefore be built large to displace sufficient air to weigh as much as the ship and its load. Water weighs 62.4 pounds per cubic foot, while air weighs only about 1¼ ounces per cubic foot. The gas capacity of some of the modern dirigibles will give a comparison of their sizes:

The *Graf Zeppelin*	3,708,000 cubic feet
The *Hindenburg*	7,063,000 cubic feet

In the early experiments with balloons they were inflated with warm air or the gases from smoldering straw. These gases served their purpose until they cooled; then the balloon would no longer have buoyancy enough to hold it in the air. As early as 1783 Professor Charles filled a balloon with hydrogen, the lightest gas known. This balloon soared over Paris and traveled a distance of nearly twenty miles. Since this early attempt hydrogen has been used extensively in balloons and dirigibles, but is being replaced, especially in the United States, by helium, which, though heavier, is not explosive. Many dirigibles have met disaster through the explosion of the hydrogen gas. Helium is found issuing from the ground with other natural gases in certain wells in Oklahoma and Texas. It is obtained from this gas by refining. Figure 519 shows a section of a dirigible illustrating how the gas is contained inside the outer fabric.

What is the history of heavier-than-air devices? The foundations for the first power flight by a heavier-than-air craft in 1903 were made between 1887 and 1903. It is interesting to note that Sir Hiram Maxim in England and Professor S. P. Langley in America were both at work between 1890 and 1900 on preliminary experiments dealing with air flight. Both built planes which, although not practicable for flight, did much to further the progress of this infant science. In 1896 Otto Lilienthal, a German, was killed while experimenting with a glider in Germany. The account of this accident in the newspapers came to the notice of Orville and Wilbur Wright, then living in Dayton, Ohio. They became interested in air flight and



Courtesy Goodyear Tire and Rubber Company

FIG. 519. CROSS SECTION OF A MODERN DIRIGIBLE

began to read the few books dealing with the subject. After long planning and much careful observation of birds, they built a series of gliders which taught them many things about flying. At the close of 1901, although they had made progress, they were discouraged and ready to go back to their bicycle business in Dayton. During the winter, however, their interest revived and they built the first wind tunnel to carry on experiments with model planes and gliders. These experiments resulted in another glider which had wings thirty feet long and five feet wide. This proved a marked success and led them to plan a machine which would carry an engine. This plane was ready late in 1903 and was assembled at Kitty Hawk, North Carolina. On December 17, 1903, Orville Wright made the first airplane flight lasting only twelve seconds and covering a distance of about 120 feet. This plane was destroyed a few days later by a strong wind, but other planes were built by the Wright brothers, each improving on the one before. Figure 520 shows the first Wright plane in flight at Kitty Hawk, N.C.

International News Photos

FIG. 520. FIRST WRIGHT PLANE

Why does the airplane stay up? If you have ever held your hand or a piece of cardboard out of the window of a rapidly moving automobile you know that air can exert a great force against a surface moving through it. By studying the forces which act upon a kite we can clearly understand how the airplane can fly even though it is heavier than air.

When a kite is flown into the wind the surface of the kite deflects the wind downward as shown in Figure 521. This tends to create a push against the kite surface which with the force exerted on the string offsets the weight of the kite. This keeps the kite in the air.

Have you ever observed the shape of an airplane wing? One is as shown in Figure 522. As the plane is pulled through the air by the rapidly turning propeller the air currents act on the wing as shown in the diagram. The downward curve of the wing tends to deflect the air currents in the same manner as the kite does. This creates a push against the bottom of the wing. The air currents which pass over the top of the wing are not able to follow its curve so readily as those which go under the wing. This causes a low pressure or suction above the wing which tends to draw the wing upward. Under these two forces and by the aid of the rear elevators the plane is able to rise from the ground. All parts of the plane are constructed to offer the least resistance to air. This is called *streamlining*.

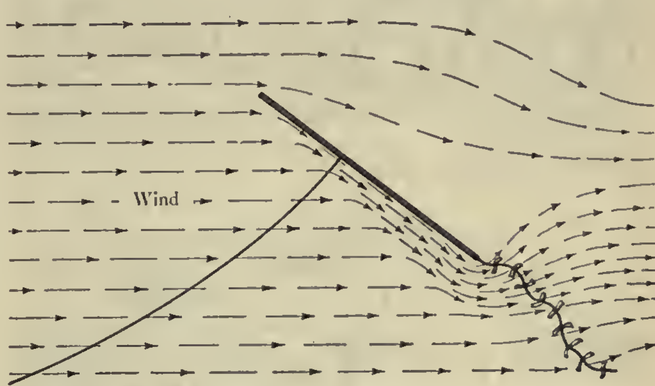


FIG. 521. DEFLECTION OF WIND BY A KITE

How is the airplane controlled? Controlling the airplane involves taking off from the field, steering, turning, and landing. Figure 523 shows a view of the controlling devices on an airplane and what each part does. Steering is controlled by the vertical fin and rudder. The plane is moved to the left or right by moving the rudder-bar with the feet and is nosed up or down by the elevators, which are moved from the control stick. The ailerons, one in either wing, are controlled from the control stick and prevent sideslipping when the plane is bank turning at high speeds.

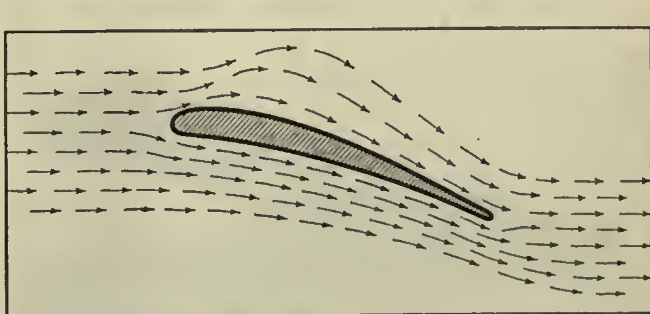


FIG. 522. AIR FLOW ACROSS AN AIRPLANE WING

They also aid in balancing the plane when it is flying level. Figure 524 shows a modern plane.

What are some of the achievements of the airplane and the dirigible? In 1906 Santos-Dumont drove an airplane at a speed of twenty-five miles an hour. Ten years later the speed record had been increased to

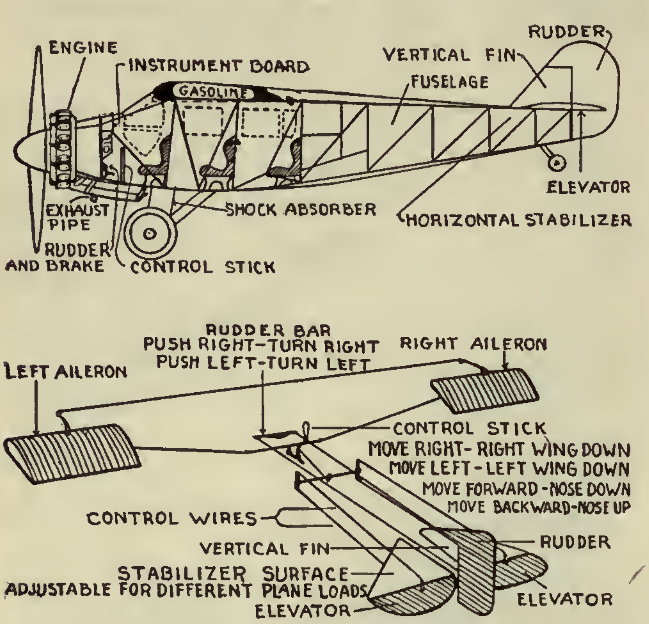


FIG. 523. CONTROLLING DEVICES OF AN AIRPLANE

more than one hundred fifty miles an hour. The longest intermittent flights on record are those made by four American aviators who circled the globe in 1924 and that of Kingsford-Smith between 1928 and 1930. The Atlantic Ocean was first crossed in 1919 when the *NC4*, a United States Navy plane, made the crossing in intermittent flights. The first non-stop flight across the Atlantic was made by Alcock and Brown in June,

FIG. 524. MODERN AIRPLANE

1919. Since these pioneer long-distance flights the achievements of the airplane have continued. The United States has been crossed in less than twelve hours, both poles have been conquered in the air, the Pacific has been crossed, and the Atlantic has been crossed many times.

Airplanes have proved effective machines of war and have been used successfully for exploring the atmosphere. The official altitude flight record in an airplane at this time is 43,976 feet held by Flight Lieutenant Uwins of the British Royal Air Force.

International News Photos

FIG. 525. HELICOPTER

The present endurance record for airplanes is held by Jackson and O'Brien, two St. Louis aviators who stayed in the air through frequent refuelings for a period of 647 hours and 28 minutes.

Santos-Dumont, a Brazilian, applied the gasoline engine to an airship and in 1901 won a prize of $20,000 for a twenty-mile flight. In July, 1919, a British ship, the *R-34*, first crossed the Atlantic Ocean to the United States. The westward crossing required four days, while the eastward return was made in three days. On October 15, 1928, the *Graf Zeppelin* flew from Friedrichshafen, Germany, to Lakehurst, New Jersey, in 111½ hours. This was the first passenger-carrying balloon to cross the Atlantic on a scheduled flight. In 1929 this same ship carried passengers and freight around the world in twenty-one days. The *Graf Zeppelin* now makes scheduled flights during each year to South America and to North America.

Courtesy Goodyear

FIG 526. COUNT ZEPPELIN

What are some of the recent developments in aviation? One of the newer developments in air travel is the helicopter. This device is designed to take off

and land almost vertically by means of four large revolving blades mounted over the plane. Sometimes the large revolving blades do the work of both propeller and wings. In some cases the blades are used along with an ordinary plane.

International News Photos

FIG. 527. AUTOGYRO

The autogyro differs from the helicopter in that the blades are not power driven from the engine but are set in motion by the wind currents created when the plane moves forward. Figure 525 shows a picture of a helicopter while Figure 527 shows the autogyro.

Of what importance are the airplane and the dirigible in transportation? Transportation by air has developed to the point where one can travel by plane to almost any point in Europe or the United States. Air lines connect all important cities and maintain a schedule almost as regular as that of the railroads or steamship lines.

There are today more than 30,000 miles of airlines in this country that maintain regular schedules. There are also some 22,000 miles of airlines that connect this country with Cuba, Mexico, South America, and Canada. These lines carry passengers, mail, and express. During 1935-1936 air mail service was opened between the Philippine Islands and the United States operating on about a five-day schedule each way. Figure 528 shows a picture of the *China Clipper*, the first ship in the service of this new line.

Paul's Photos

FIG. 528. THE *China Clipper*

In 1934 scheduled airplanes in the United States carried more than a half million people an average distance of four hundred miles, transported 3,500,000 pounds of air express and 8,000,000 pounds of mail.

The U. S. Bureau of Air Commerce has established one of the finest systems of airways to be found anywhere in the world. In their service to aviators flying these routes they provide:

1) teletype service on the movement of planes and on weather conditions;

2) rotating beacon lights at intervals of ten to fifteen miles for night flying;

3) landing fields every fifty miles to be used in cases of emergency;

4) radio beacons every twenty-five to one hundred miles;

5) radio landing beams at fields which enable planes to land "blind" in fogs;

6) radio communication to planes which enable the sending of emergency messages and weather conditions to pilots.

Figure 529 shows the network of airlines which cover the United States.

Dirigibles are coming into use for transoceanic transportation of passengers and express. The *Graf Zeppelin* and the *Hindenburg*, German owned ships, fly to South America at frequent intervals and have recently established a line to the United States.

REFERENCES FOR FURTHER STUDY

Texts

Caldwell and Curtis, *Science for Today*, Chap. 28

Clement, Collister, and Thurston, *Our Surroundings*, Chap. 20 (part)

Hunter and Whitman, *Science in Our World of Progress*, Unit 9

Lake, Harley, and Welton, *Exploring the World of Science*, Chap. 25 (part)

Pieper and Beauchamp, *Everyday Problems in Science*, Unit 17

Powers, Neuner, and Bruner, *Man's Control of His Environment*, Chap. 19

Van Buskirk and Smith, *The Science of Everyday Life*, Chap. 20

Webb and Beauchamp, *Science by Observation and Experiment*, Unit 3

Wood and Carpenter, *Our Environment: How We Use and Control It*, Topic 11 C

Special references

Compton's Pictured Encyclopedia

Verrill, *Aircraft Book for Boys*

Molter, *Knights of the Air*

Collins, *How to Fly*
Collins, *The Boys' Airplane Book*

WHAT YOU SHOULD AIM TO ACQUIRE FROM THIS STUDY

1. Something of the early history of air transportation.
2. An understanding of how balloons and dirigibles float in air.
3. How heavier-than-air machines rise in air and are propelled through it.
4. The present value of airplanes as a means of travel and transportation and their possibilities in the future.

TEST OF MASTERY OF THE TOPIC

In your notebook complete the statements, answer the questions, and comply with the instructions.

1. The first balloon was built by ____ in ____.
2. The first dirigible was propelled by a ____ engine.
3. ____ constructed the first rigid dirigible.
4. ____ is usually used in constructing the framework of a rigid dirigible.
5. Balloons are able to rise and float in air because they ____ air which weighs ____ than their own weight.
6. ____ and ____ are the gases commonly used in the modern dirigible.
7. The lightest element known is ____. This is not entirely satisfactory for use in balloons because it is ____.
8. Another gas, ____, is obtained from natural gas wells in Oklahoma and Texas.
9. Balloons and dirigibles are controlled by the principle of ____.
10. A balloon is buoyed up by a force equal to the ____ of ____ displaced.
11. What are the three types of dirigibles?
12. ____ discovered the principle of buoyancy.
13. Airplanes are (heavier, lighter) ____ than air.
14. The first airplane flight was accomplished in ____ by ____ at ____.
15. Write a paragraph explaining how the airplane wing is constructed to enable the plane to lift.
16. When an airplane is in flight the air currents create a ____ below the wing and a ____ above the wing which enable the plane to lift.
17. Streamlining means ____.
18. Tell the part played by each of the following in controlling an airplane: rudder, aileron, rudder bar, vertical fin, elevator, control stick.
19. Explain how the aviator can accomplish the following: nose the plane up, bank the plane, nose the plane down.
20. What is the difference between the helicopter and the autogyro?
21. Write a statement of your views on air travel as the transportation of the future.

Courtesy U. S. Department of Commerce, Bureau of Air Commerce

FIG. 529. AIRWAY MAP OF THE UNITED STATES

SUPPLEMENTARY MATERIALS

Reading suggestions

Bond, *With the Men Who Do Things* (Scientific Am. Pub.)

Parkman, *Conquests of Invention* (Century)

Talbot, *All About Aircraft of Today* (Funk)

U. S. Bureau of Education, *Bulletin No. 38, Mainstreets of the Nation*

Homans, *Automobile Handbook* (Sully)

Darrows, *Boys' Own Book of Great Inventions* (Macmillan)

Moffett, *Careers of Dangers and Daring* (Century)

Reed, *Railway Engines of the World* (Oxford)

Bryan, *Aerial Transportation* (Anderson Press)

Collins, *Aviation and All About It* (Appleton)

Garber, *Building and Flying Model Aircraft* (Ronald)

Hawks, *Romance of Transport* (Crowell)

Jackson, *The Book of the Locomotive* (Longmans)

Jackson, *The Romance of the Railway* (McClelland & Stewart)

Kneen, *Everyman's Book of Flying* (Stokes)

Klemin, *If You Want to Fly* (Coward-McCann)

Van Metre, *Trains, Tracks, and Travel* (Simmons-Boardman)

Reports which may be prepared

1. The lives and works of the Wright brothers
2. The life and work of Robert Fulton
3. The life and work of Henry Ford
4. A survey of the transportation facilities of your own locality
5. The history of aviation
6. The invention and development of steam engines
7. The history of the development of ships since the time of Columbus
8. The development of submarines
9. The development of aviation in the United States
10. Historic dirigibles
11. The history of the dirigibles
12. The dirigible airlines of the world
13. The history of the compass
14. How direction and position are told at sea
15. Flying blind
16. The development of safety devices for air travel
17. The automatic pilot used on airplanes
18. The development of the streamlined train
19. The streamlined automobile.

Great scientists and inventors you should know about

1. James Watt
2. Robert Fulton
3. Wright brothers
4. Henry Ford
5. Archimedes

Investigations and things to do

1. Set up an electric motor and demonstrate how it works.
2. Make a toy model airplane and demonstrate it.
3. Make a small sailboat.
4. Make toy water wheels to demonstrate the different types.
5. Examine a toy electric train. Study the construction of the engine.

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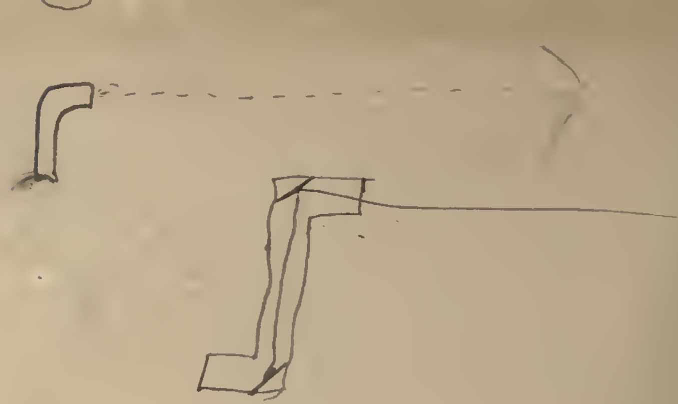

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